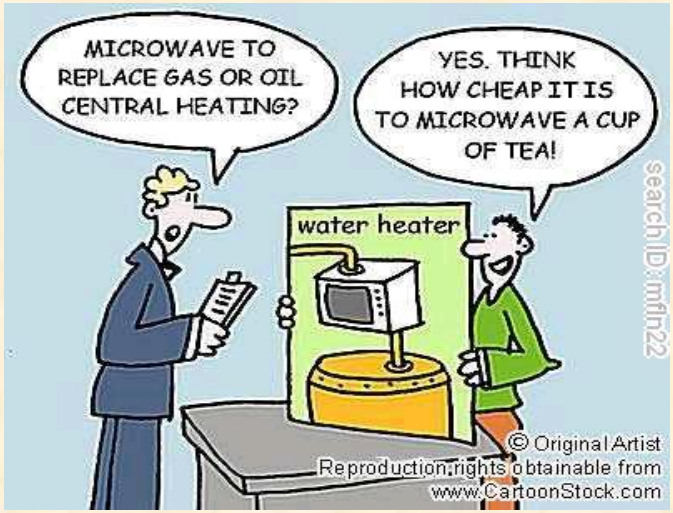
Acoustic Power Generation : Reverse Engineering the human ear

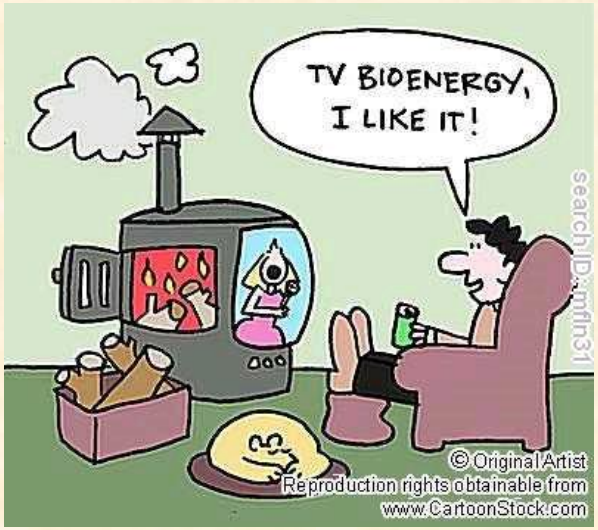
1. Praveen Kumar N
2. Suraj Srinivas
3. Pramukh Bharadwaj MV

II Semester K section (ECE)
PES Institute of Technology

"The more I study nature, the more I stand amazed at the work of the Creator."
--Louis Pasteur



Conventional and Non Conventional energy sources, Conversion, Storage

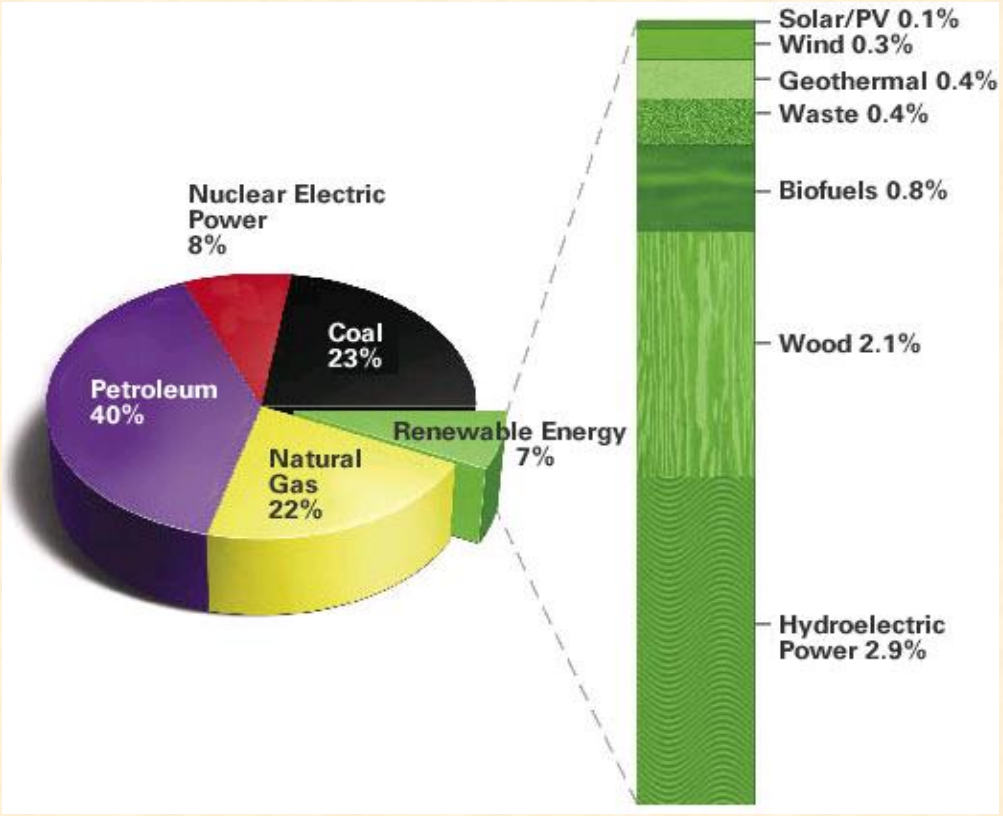


Contents

- Introduction – Present energy scenario
- Why select sound energy?
- How much of sound energy are we wasting?
- Principle – Piezo electric effect
- Inspiration from human ear
- Sound to electricity conversion procedure
- Expected Energy
- Advantages of Acoustic power generator
- Applications
- Way forward

Introduction – Present energy scenario

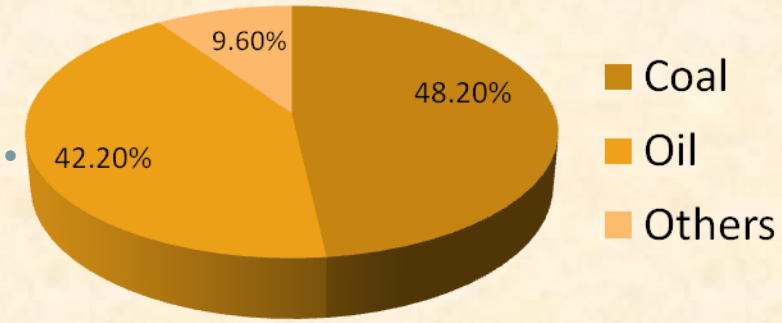
The world mainly depends on fossil fuels (coal, petroleum and natural gas) with **85%** of our energy requirements satisfied by fossil fuels



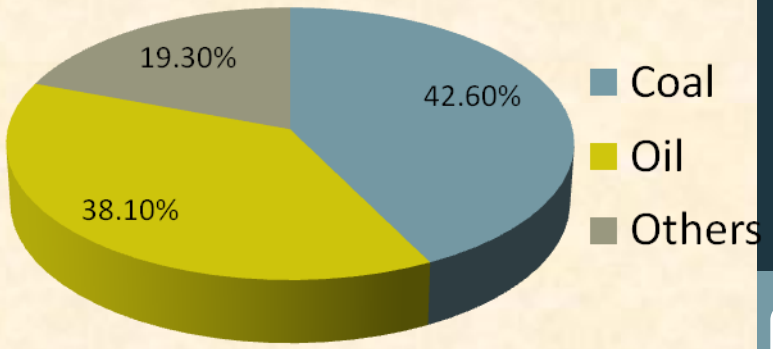
Introduction – Present energy scenario

The popular conventional energy sources pose environmental concerns with fossils fuels contributing for about **90%** of sulphur oxides and **80%** of carbon di-oxide emission

Sulphur oxides emmision percentages

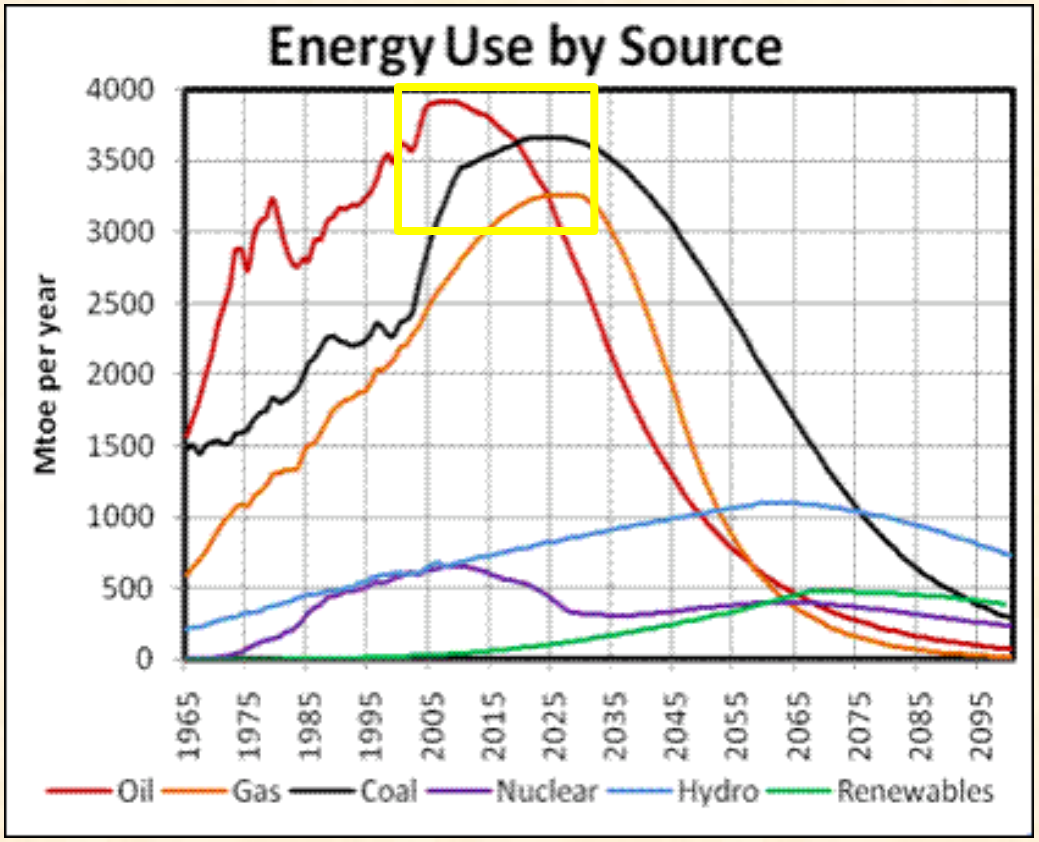


Carbon di oxide emissions percentages



Introduction – Present energy scenario

They are also nearing exhaustion. Graph indicates steep downturn in fossil fuels availability around year **2030**

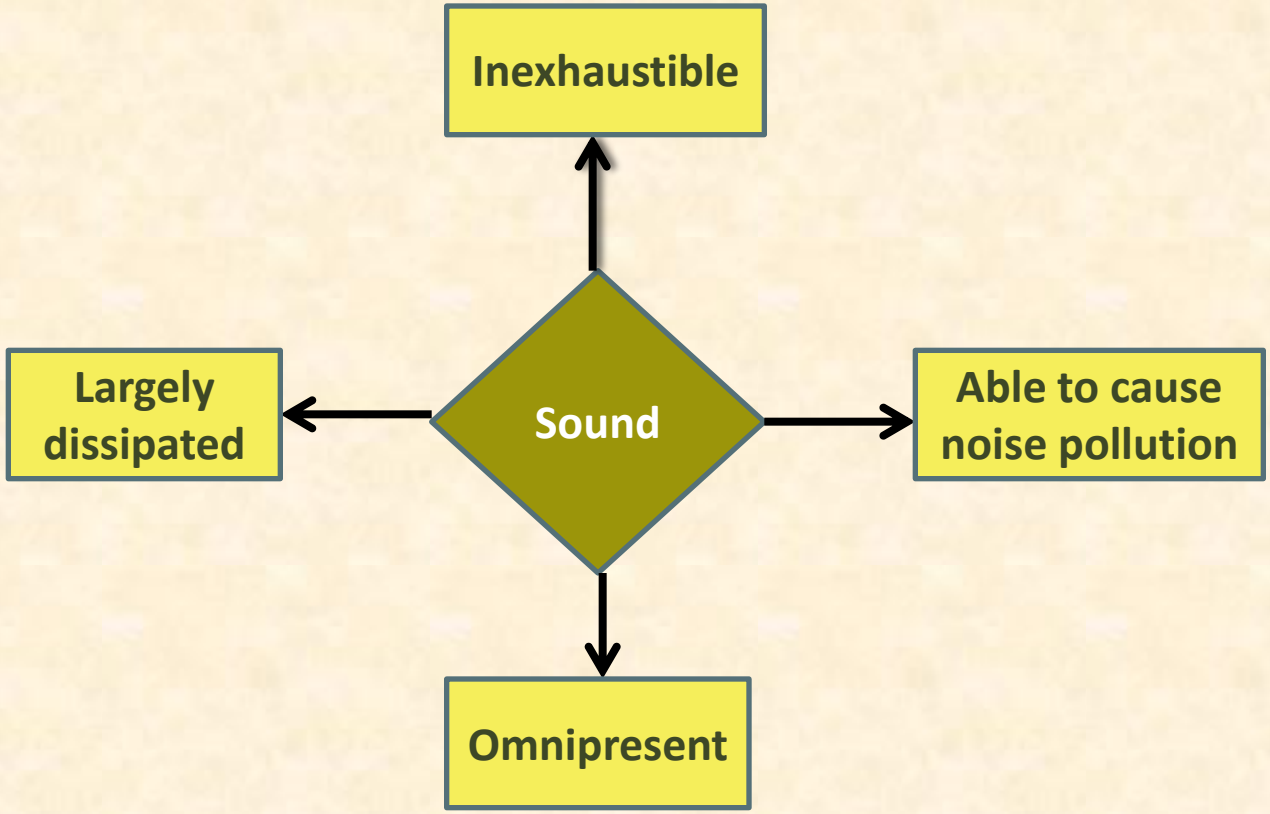


Introduction – Present energy scenario

Thus the various non conventional , renewable , greener energy sources need to be tapped.

- Solar Energy
- Wind energy
- Geothermal energy
- Ocean energy
- Biomass Energy
- Sound Energy

Why select sound energy?



How much sound energy are we wasting ?

Case 1: Industry: Consider a processing factory with **250** heavy machines, each emitting sound of loudness **110db** ie an intensity of **0.1W/sq.m** running for **10 hr** a day for **1 year**. The energy per unit area that can be used is

$$E = (250)(1mW)(10hr)(365days)$$

$$E = (250)(1mW)(36000s)(365)$$

$$E = 328500000\ J$$

$$\mathbf{E = 328MJ}$$

How much sound energy are we wasting ?

Case 2: Road Traffic:

Total road length in India is 32 lakh km. If one acoustic plant is set up for every 50m there will be **6.4 crores** in total. Considering average traffic loudness to be **90 db** ie of intensity **1mW/sq.m** running for **15 hr** daily, and assuming efficiency of power generator energy to be 100% energy that can be harnessed per unit area in **1 year** will be :

E = n * P * t

where n is number acoustic generators

E = (64000000) * (1mW) * (15h)(365days)

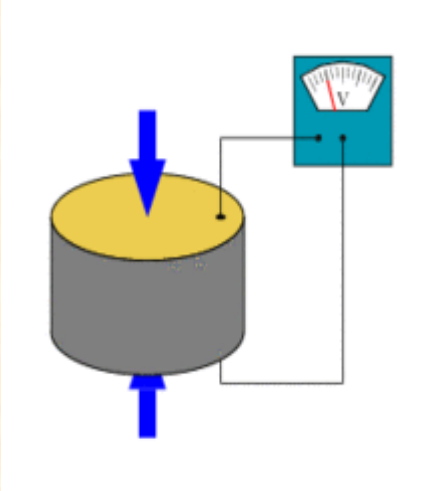
E = (64000000)(1mW)(54000s)(365)

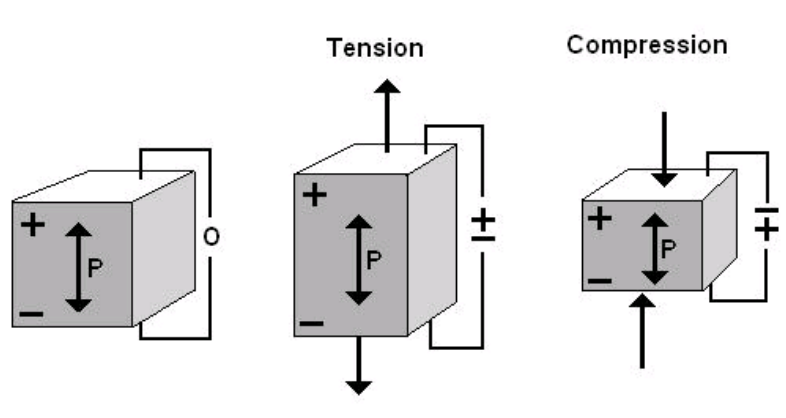
E = 126144000000 J

E = 126GJ

Principle : Piezoelectric Effect

- Accumulation of charges (flow of electricity) on certain solids in response to the applied mechanical stress is called piezoelectric effect.
- Flexoelectric effect is phenomenon where voltage is induced due to a strain gradient in the crystal.
- Quartz, rochelle's salt, barium titanate,lead zincronate titanate, polyvinilidene flouride are good piezoelectric crystals.



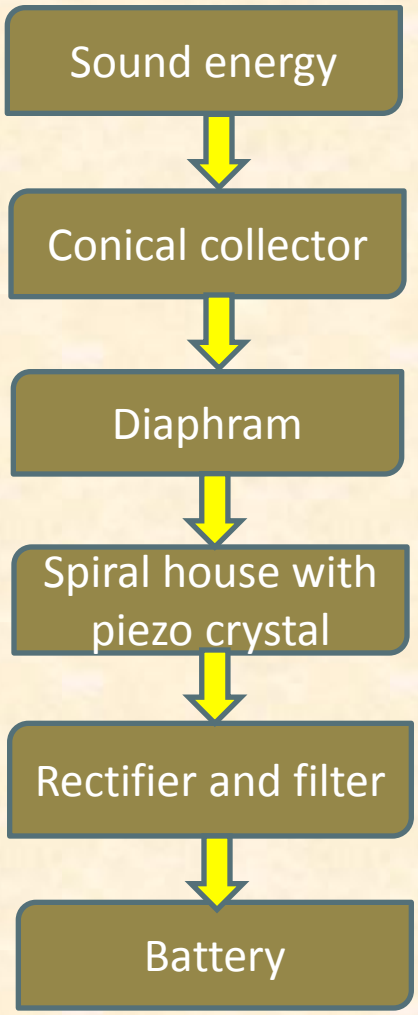


On these lines, sound (mechanical energy) can be converted to electrical energy

Inspiration from the human ear

Function	Human ear	Acoustic power generator
Input	Sound	Sound
Sound collector	Outer ear	Conical collector inlet
Sound guide	Ear canal	Conical collector
Amplification	Converging ear canal	Conical collector and spiral house
Fluid	Perilymph , Endolymph	Water or glucose solution
Receptors	Nerve cells	Piezoelectric crystal
Output	Electrical impulses	Electric current

Conversion procedure



Conversion Procedure

1. Sound Source:

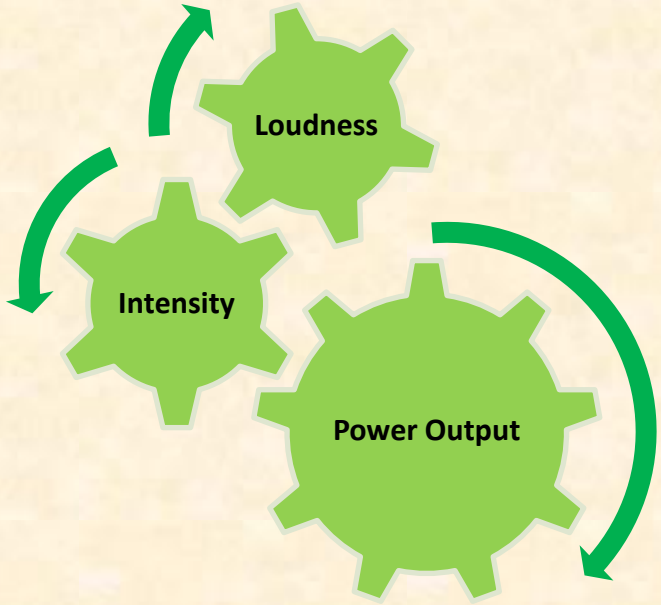
- Any continuous sound source can be used
- Louder the sound , louder the intensity. Intensity increases with loudness in a logarithmic scale

L=10log(I/10^-12)

where , L loudness of sound in db

I is intensity of sound

- Louder the intensity greater is the power output.



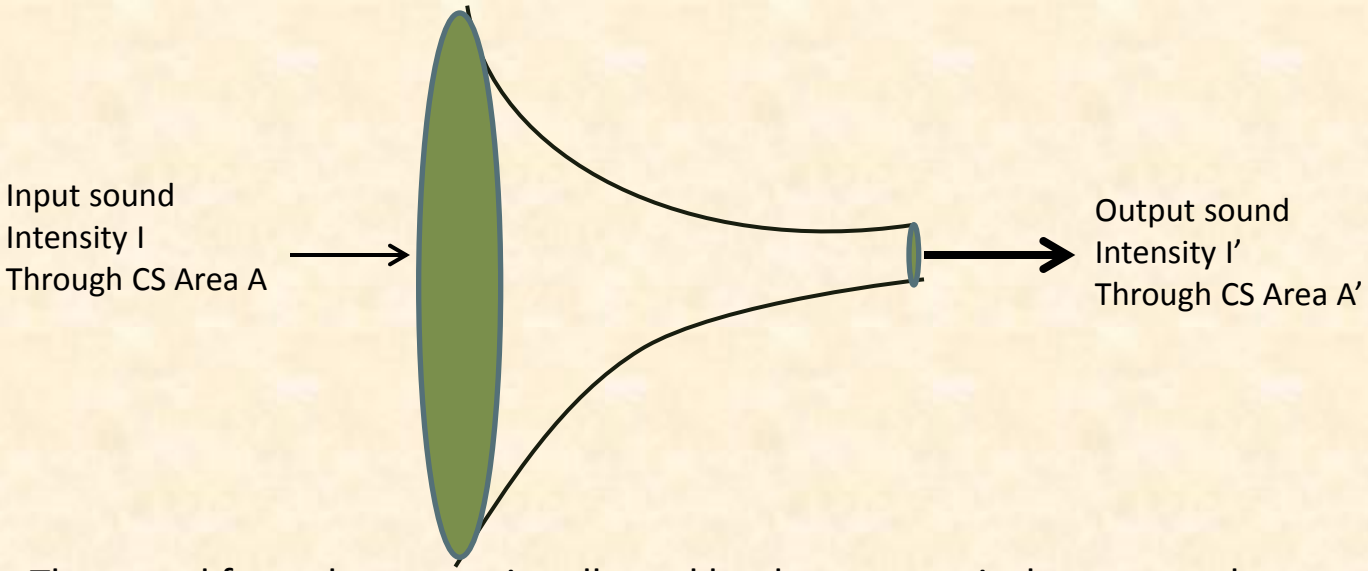
Conversion Procedure

Target sound sources are

Target sound sources	Loudness in db	Intensity in W/sq.m
Road traffic	90	0.001
Industry – Heavy machinery Air compressor Milling machines Textile loom Boilers Sirens	100-110	0.01-0.1
Plane and Jet takeoff	110-150	0.1-1000

Conversion Procedure

2. Conical collector:



The sound from the source is collected by the near conical structure shown.

Sound intensifies as it travels through it.

For any sound, **P=IA**

where P is power and A is area I is intensity of sound

According to the Law of Conservation of Energy

Input Power = Output Power

IA = I'A'

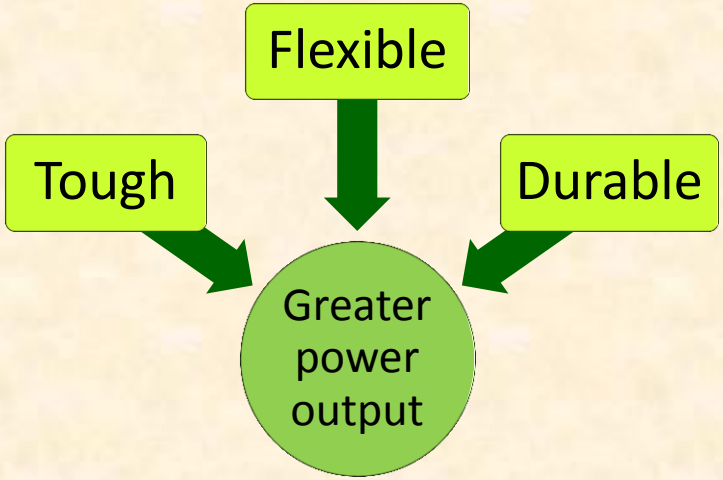
I' = I*A/A'

Conversion Procedure

3. Diaphragm :

Diaphragm is fixed at the output end of the conical structure

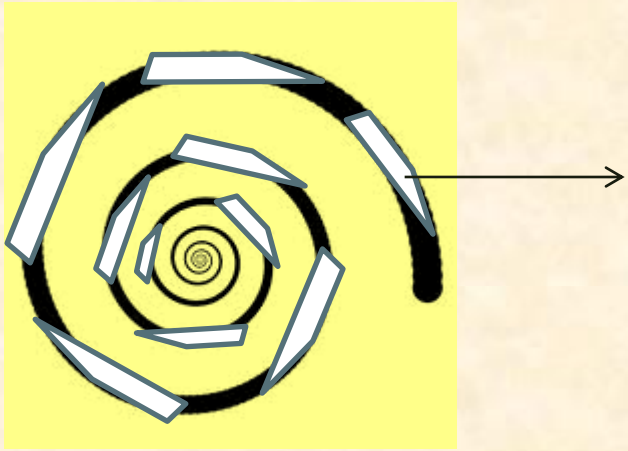
They transfer the sound vibrations to the next stage (spiral house)



Natural Rubber or Silicone rubber can be used

Conversion Procedure

4. Spiral house :



- The outlet of conical collector and the inlet of spiral house are connected via a diaphragm
- The area of spiral house is continuously decreasing to provide further amplification.
- For a given conical collector, the output intensity increases with decreasing outlet area of spiral house.
- The spiral house is filled with water to reduce energy losses
- Spiral house houses an array of piezoelectric crystals

Conversion Procedure

5. Piezoelectric crystal :

- The spiral house houses an array of piezoelectric crystals (quartz) for gradual energy absorption (compounding)
- The crystals are arranged such that the pressure waves are incident on the crystal along that crystallographic axis which lies on the bond line which produces maximum intra-molecular deformation.
- Deformation of the molecules results in a net dipole moment and leads to charge accumulation on the surface

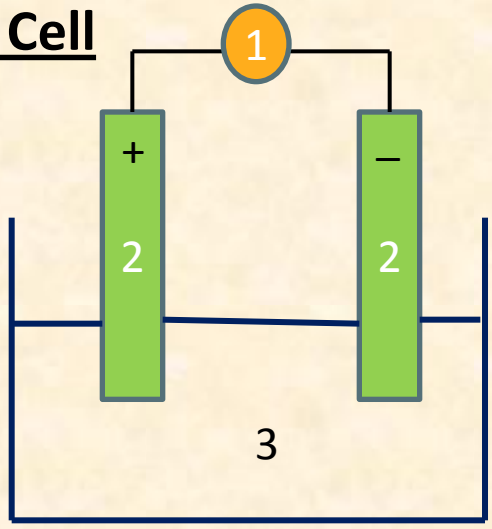
Conversion Procedure

6. Rectifier and Filter:

- The output current from the crystal is a haphazard signal
- This is smoothened by using proper electronics
- A output from crystal is fed to a rectifier to obtain a direct current
- The small remaining ac component is removed by the filter
- A smooth dc voltage is thus obtained

Conversion Procedure

7. Storage: ATP Cell



1 – Voltage supply
2 - Electrodes
3 - Acidified soln. of Phosphate ions + ADP+ ATP sythesizer

- Voltage is applied to electrodes dipped in a solution of ADP (adenosine di phosphate),phosphate ions and the enzyme ATP (adenosine tri phosphate) synthesizer

ADP + Phosphate ions —DC Voltage→ **ATP**

- ADP is converted into ATP thus storing the electrical energy produced

Calculations : Absorption of sound by crystal

- Let the acoustic absorption co efficient of the crystal per unit area be ಕಅ.
- Let the areas of the two ends of the spiral be ಂ & ಎ (ಎ>ಂ).
- The intensity amplification = ಎ/ಂ
- Now, the input sound waves will effectively be incident on an area equivalent to ಎ-ಂ.
- Hence, the intensity of sound absorbed will be

ಐa= (ಎ-ಂ)* ಕಅ* ಐi

where ಐi is the sound intensity incident

Calculations – Expected Output Voltage

The charge (Q) developed by surface is directly proportional to the applied force (F) .

$Q = F*d$ where d is proportionality constant

$C = KA/t$ where K is permittivity

$V = Q/C$

$V = (d/K)*(t)*(F/A)$ eq.1

$V = gtP$

Where P is applied pressure, t is thickness and g is voltage sensitivity of the crystal

Considering sinusoidal pressure wave,

$V=gt(P_{max}\sin(wt))$

$V=V_o \sin(wt)$ where $gtP_{max} = V_0$

Hence the maximum voltage developed is proportional to the maximum pressure of the sound wave.

Design Options

Two design options are suggested

Macro Design	Micro Design
Frequency dependant applications	Frequency independent applications
Uses resonance pipes	Uses levers for amplification
No levers	Uses levers for mimicking the action of auditory ossicles to provide greater amplification
Can be used in limited numbers	Can be used in large numbers

Advantages

- Continuous and inexhaustible input supply
- Output hardly dependent on geographical location
- The generator uses energy which is otherwise wasted
- Eco friendly
- Minimum Investment
- Occupies less space
- Sleek
- Potable
- Easy construction
- Can have an acoustic power generator in our own homes

Applications

1. Engine mapping
2. Spyware applications , Burglar alarms
3. Seismograph
4. Prediction of tectonic movement
5. Noise survey
6. Small scale electricity source
7. Energy Supply to human body by the ATP cell
8. Multiple Generators in auditoriums
9. In everyday life to power cell phone s and other small devices

Way forward

1. The power output is not very high, right now.

2. But we believe that, given enough time and research on this particular topic, we can certainly come up with more efficient ways to build on the idea.

3. Taking inspiration from **Michael Faraday**, who first used a galvanometer to show the small current induced by EMI, we have the attitude of nurturing this toddler to dizzying altitudes.

"To know how to wait is the greatest secret of success"
-- De Maistre

References

1. Nature
2. Wikipedia


THANK YOU