Energy – Global and National Issues

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Language

- Please interrupt and ask when in doubt
- Use Turkish or English as you prefer
- It is important that you follow the talk
Energy consumption for countries

Source: World Resources Institute

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Energy and Life Expectancy (2000)

Source: World Resources Institute

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Energy and Fertility (2000)

Source: World Resources Institute

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# Energy Units

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<thead>
<tr>
<th></th>
<th>1 terawatt (TW)</th>
<th>1 Quad</th>
<th>1 toe (tonne of oil equivalent)</th>
<th>1 petajoule (PJ)</th>
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<tbody>
<tr>
<td></td>
<td>$10^{12}$ W</td>
<td>1060 PJ</td>
<td>$10^7$ kcal</td>
<td>$10^{15}$ J</td>
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Electricity drives modern economy

Huber & Mills, “The Bottomless Well”, US Data

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World Electricity Consumption

• The world electricity consumption \(^{(1)}\) in 1997
  – About 12 trillion kWh/year
  – Or about
    • 2102 kWh/person/year
    • 0.240 kW/person

• in Turkey?

Electrical Generation Capacity Growth in Turkey

Turkish Installed Capacity Growth

Year

Installed Capacity (MWe)
This looks like exponential growth. Let us fit a curve.

\[ \text{GWH} = \text{GWH}_0 \ e^{a(Y-1974)} \]
Plot the logarithm of consumption

Fit a line
\[ y = mx + n \]
Electricity Consumption Curve Fit

Electricity Usage in Turkey

The blue line is our curve

\[
\text{GWHe} = n e^{m(Y-1974)}
\]

where \( m = 0.0755 \) and \( n = 14488 \) are from the linear fit on the previous slide.

The ‘circles’ are the TEIAS data.


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Projection into the future

Past and Projected Electricity Usage in Turkey

- TEIAS past data
- TEIAS estimated future demand
- Our curve for future demand

Net consumption, '000 GWh

Years

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The approaching crisis
Energy in the Future

No one knows what it will be except different!
The Context

• Today, a discussion on energy futures is inextricably linked with a discussion on global warming

• The scarcity issues are still relevant but are only of second order importance
Fact Page - 1

- The 10 warmest years on record have all been since 1990. Over the last century average global temperatures have risen by 0.6°C: the most drastic temperature rise for over 1,000 years.
- Extreme events are becoming more frequent. Glaciers are melting. Sea ice and snow cover is declining. Animals and plants are responding to an earlier spring. Sea levels are rising and are forecast to rise another 88cm by 2100 threatening 100m people globally who currently live below this level.
- The number of people affected by floods worldwide has already risen from 7 million in the 1960s to 150 million today.
Fact Page - 2

• In Europe alone, the severe floods in 2002 had an estimated cost of $16b
• These environmental changes and severe weather events are already affecting the world insurance industry. Swiss Re, the world's second largest insurer, has estimated that the economic costs of global warming could double to $150 billion each year in the next 10 years, hitting insurers with $30-40 billion in claims.
• By the middle of this century, temperatures could have risen enough to trigger irreversible melting of the Greenland ice-cap - eventually increasing sea levels by around seven metres.
• There is good evidence that 2003 European heat wave was influenced by global warming. It resulted in 26,000 premature deaths and cost $13.5 billion.
• It is calculated that such a summer is a one in about 800 year event. On the latest modelling climate change means that as soon as the 2040s at least one year in two is likely to be even warmer than 2003.
“The emission of greenhouse gases … is causing global warming at a rate that began as significant, has become alarming and is simply unsustainable in the long term.

And by long term I do not mean centuries ahead. I mean within the lifetime of my children certainly; and possibly within my own.

And by unsustainable, I do not mean a phenomenon causing problems of adjustment.

I mean a challenge so far reaching in its impact and irreversible in its destructive power; that it alters radically human existence…

There is no doubt the time to act is now.”

*Tony Blair, Address to the 10th anniversary of HRH’s Business & Environment Forum, 14 Sep 2004*

[http://www.number-10.gov.uk/output/page6333.asp](http://www.number-10.gov.uk/output/page6333.asp)
What is a Greenhouse?

Greenhouses are used to grow commercial plants in relatively cold climates. The sunlight can enter through the glass roof and walls. The heat inside is radiated at a higher wavelength and is trapped by the glass. The trapped heat increases the inside temperature while the building is exposed to sun. The commercial greenhouses must have ventilation and shading controls to prevent overheating. The mechanism is similar to the interior of a car getting hot when the car is exposed to sunlight.

Open-roof greenhouse at the Horticultural Research Farm # 3 at Rutgers University. aesop.rutgers.edu/~horteng/openroof.htm

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The solar radiation impinging our upper atmosphere is very close to ideal blackbody radiation at 5900 °K. A large part is in the visible spectrum.

The earth absorbs part of the incoming radiation and re-radiates it back in the infrared region (similar to ideal blackbody radiation at earth temperatures).

Greenhouse gases absorb part of this re-radiated heat.
Earth’s radiation absorbed by greenhouse gases
The earth is just right!

The earth would be too cold like Mars if the natural greenhouse effect did not warm our planet. On the other hand, the earth would be too hot like Venus if we had too much greenhouse gas. The Mars’ blanket is too thin, the Venus’ blanket is too thick. The earth is just right.
Global Warming Potential (GWP)

• The Global Warming Potential (GWP) is a simplified index that can be used to estimate the potential future impacts of emissions of different gases upon the climate system in a relative sense.

• Reference values for GWP of significant greenhouse gases are published by the Intergovernmental Panel of Climate Change (IPCC).

• The calculations are based on a 100-year horizon.

• Methane has a GWP value of 23. This means that methane is 23 times more effective at trapping heat in the atmosphere when compared to CO₂ over a 100-year time period.
# Greenhouse Gases (GHG)

*Table 4.1(a) of “Climate Change : Scientific Basis – 2001” by IPCC*

*Chemically reactive greenhouse gases*

<table>
<thead>
<tr>
<th>Chemical species</th>
<th>Formula</th>
<th>Lifetime (yr)</th>
<th>100-yr GWP b</th>
</tr>
</thead>
<tbody>
<tr>
<td>Methane</td>
<td>CH₄ (ppb)</td>
<td>8.4/12 c</td>
<td>23</td>
</tr>
<tr>
<td>Nitrous oxide</td>
<td>N₂O (ppb)</td>
<td>120/114 c</td>
<td>296</td>
</tr>
<tr>
<td>Perfluoromethane</td>
<td>CF₄</td>
<td>&gt;50000</td>
<td>5700</td>
</tr>
<tr>
<td>Perfluoroethane</td>
<td>C₂F₆</td>
<td>10000</td>
<td>11900</td>
</tr>
<tr>
<td>Sulphur hexafluoride</td>
<td>SF₆</td>
<td>3200</td>
<td>22200</td>
</tr>
<tr>
<td>HFC-23</td>
<td>CHF₃</td>
<td>260</td>
<td>12000</td>
</tr>
<tr>
<td>HFC-134a</td>
<td>CF₃CH₂F</td>
<td>13.8</td>
<td>1300</td>
</tr>
<tr>
<td>HFC-152a</td>
<td>CH₃CHF₂</td>
<td>1.40</td>
<td>120</td>
</tr>
</tbody>
</table>

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The past and the future

LAST 400,000 YEARS: ATMOSPHERIC CO₂ (200-280 ppm)

ESTIMATED EFFECTS
450ppm: (1.2 - 2.3°C)
550ppm: (1.5 - 2.5°C)
650ppm: (1.7 - 3.2°C)

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CO₂ Sources

- Power: 35%
- Transport: 24%
- Manuf: 18%
- Residential: 14%
- Other: 9%

"Overview of CO2 capture", Kelly Thambimuthu, GHGT-7, Vancouver, 5-9 September 2004

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The focus is on reducing CO2 emissions in power generation industries.

Transport is next big fraction but can probably be replaced only by direct or indirect electricity, i.e., more power generation.

Residential heating is important but this is mostly in undeveloped world and not easy to change.
Past and Future CO₂

“IEA World Energy Investment Outlook”, Marianne Haug, Director, IEA Energy Technology, GHGT-7, Vancouver, 5-9 Sep 2004

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CO₂ Emissions in 2002

World Total CO2 Emission in 2002 = 24 billion tonnes (38b t projected for 2030)

"IEA World Energy Investment Outlook", Marianne Haug, Director, IEA Energy Technology, GHGT-7, Vancouver, 5-9 September 2004

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Projected CO_2 Emissions in 2030

World Total CO2 Emission in 2030 = 38 billion tonnes (about 10b tonnes of Carbon)

OECD 42%
Others 58%

16 b tonnes
22 b tonnes

"IEA World Energy Investment Outlook", Marianne Haug, Director, IEA Energy Technology, GHGT-7, Vancouver, 5-9 Sep 2004

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The actual numbers are difficult to know and there is variation between sources. This chart is copied from Earth Observatory, NASA, on http://earthobservatory.nasa.gov/Library/CarbonCycle.

Compare the figures of exchange with the estimates in Figure 10.7 of Fay and Golomb. Significant differences will be observed. The main uncertainty is due to the fact that when the CO2 in the air goes up, the earth tends to absorb more through photosynthesis on land (more forests) and in oceans (plankton growth).

However, it is clear that the earth cannot absorb all of the extra CO2 released to the atmosphere by human activities.

How do we know that the earth cannot absorb all of the extra CO2 released to the atmosphere by human activities?
Feedback Effects

• Rising temperatures will cause secondary effects called feedback effects:

\[ \Delta T_s \propto \frac{\Delta Q}{\beta} \]

- \( \Delta T_s \): Surface temp. rise
- \( \Delta Q \): Radiative forcing due to GHG alone
- \( \beta \): Feedback factor

• \( \beta < 1 \rightarrow \) Positive feedback (amplifying effect)
• \( \beta > 1 \rightarrow \) Negative feedback (corrective effect)
• Possible feedback effects include water vapour, cloud radiation, aerosols, ice-albedo, and ocean circulation
Water Vapour Feedback

- Water has strong absorption bands in the far-infrared region. If it were classified as a GHG, it would have a GWP higher than CO₂.
- Since water vapour continuously circulates, a given molecule does not stay in the air for decades like CO₂ or methane molecules do. Therefore, it is treated as a feedback rather than a GHG in its own right.
- Higher temperatures
  - increased evaporation from the oceans
  - more water vapour in the air
  - more absorption of the outgoing far-IR radiation
  - higher temperatures
    - and it goes on like this like any positive feedback mechanism
- Models predict water vapour feedback to increase GHG-caused global warming by about 60% (β≈0.6)
Cloud Radiation Feedback

• Clouds may have both positive and negative feedback
• Positive feedback (low-altitude cumulus-type clouds):
  – More clouds will reflect more of the incoming solar radiation
  – The earth’s albedo will increase
  – The surface temperature will decrease
• Negative feedback (high-altitude, cirrus-type clouds)
  – More clouds will reflect more of the earth’s radiation back
  – The surface temperature will increase
• Modelling of cloud feedback is very uncertain
• Fay & Golomb quote a feedback value of $\beta=0.80$, but the opinion varies
Aerosol Feedback

- Aerosols are natural or man-made small particles suspended in the air.
- Particle diameters are much smaller than 1 μm. Larger particles will fall (see the terminal velocities in the next slide).
- Roughly two-thirds caused by fossil fuel combustion.
- Aerosols scatter and reflect incoming solar radiation and therefore act as a negative feedback mechanism ($\beta \approx 1.1$).
- On the other hand, aerosols help cloud formation forming as condensation nuclei. Therefore, more aerosols mean more clouds. The cloud feedback effect is more uncertain.
Ice-Albedo Feedback

• Ice is more reflective than land or liquid water
• Therefore, more ice on earth’s surface means that more of the incoming solar radiation is reflected back without heating the earth (in other words, more ice increases earth’s albedo)
• Global warming causes ice to melt, which reduces the albedo of the earth and hence will cause a further increase of the surface temperature as a positive feedback mechanism.
• Fay & Golomb recommend $\beta \approx 0.8$. 
Ocean Circulation Feedback

• Salinity differences drive the large ocean currents, e.g. Gulf Stream
• Global warming will melt polar ice caps and will increase rainfall at higher latitudes
• Both will reduce the seawater salinity in those regions
• Ocean circulation patterns may then be switched, e.g. the Gulf Stream may reverse its direction
• The effect on global warming is not clear and could be positive, negative or neutral.
• However, the effect on human life would be very significant
• If, for example, the Gulf Stream changes its direction, the climate in most of Europe and North America would reduce to Ice Age temperatures with a radical effect on life in these regions.
The Impact on the World

The Stern Review

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The Stern Review

- Review set out to assess:
  - economics of moving to a low-carbon global economy; and
  - the potential of different approaches for adaptation to changes in the climate.
- The first major contribution to the global warming debate by an economist, rather than an environmental scientist
- Tony Blair responded to the Review by saying that the consequences of inaction were "literally disastrous":
  - "This disaster is not set to happen in some science fiction future many years ahead, but in our lifetime"
  - "Investment now will pay us back many times in the future, not just environmentally but economically as well."
  - "For every £1 invested now we can save £5, or possibly more, by acting now."
The Impact on the Economy

• Using the results from formal economic models, the Review estimates that if we don’t act, the overall costs and risks of climate change will be equivalent to losing at least 5% of global GDP each year, now and forever. If a wider range of risks and impacts is taken into account, the estimates of damage could rise to 20% of GDP or more.

• In contrast, the costs of action – reducing greenhouse gas emissions to avoid the worst impacts of climate change – can be limited to around 1% of global GDP each year.

The Stern Review – Executive Summary
The Brave New Future according to the Stern Review

- The risks of the worst impacts of climate change can be substantially reduced if greenhouse gas levels in the atmosphere can be stabilised between 450 and 550ppm CO2 equivalent (CO2e). The current level is 430ppm CO2e today, and it is rising at more than 2ppm each year. Stabilisation in this range would require emissions to be at least 25% below current levels by 2050, and perhaps much more.
- Ultimately, stabilisation – at whatever level – requires that annual emissions be brought down to more than 80% below current levels.
- Even if the rich world takes on responsibility for absolute cuts in emissions of 60-80% by 2050, developing countries must take significant action too.
- Action on climate change will also create significant business opportunities, as new markets are created in low-carbon energy technologies and other low-carbon goods and services. These markets could grow to be worth hundreds of billions of dollars each year, and employment in these sectors will expand accordingly.
### Projected Impacts of Climate Change

<table>
<thead>
<tr>
<th>Global temperature change (relative to pre-industrial)</th>
<th>0°C</th>
<th>1°C</th>
<th>2°C</th>
<th>3°C</th>
<th>4°C</th>
<th>5°C</th>
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<tbody>
<tr>
<td><strong>Food</strong></td>
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<tr>
<td>Falling crop yields in many areas, particularly developing regions</td>
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<td>Possible rising yields in some high latitude regions</td>
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<tr>
<td>Falling yields in many developed regions</td>
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<td><strong>Water</strong></td>
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<td>Small mountain glaciers disappear – water supplies threatened in several areas</td>
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<td>Significant decreases in water availability in many areas, including Mediterranean and Southern Africa</td>
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<td>Sea level rise threatens major cities</td>
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<td><strong>Ecosystems</strong></td>
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<td>Extensive Damage to Coral Reefs</td>
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<td>Rising number of species face extinction</td>
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<td><strong>Extreme Weather Events</strong></td>
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<td>Rising intensity of storms, forest fires, droughts, flooding and heat waves</td>
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<td><strong>Risk of Abrupt and Major Irreversible Changes</strong></td>
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<td>Increasing risk of dangerous feedbacks and abrupt, large-scale shifts in the climate system</td>
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Stabilisation and Commitment to Warming

Eventual temperature change (relative to pre-industrial)

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Emissions Paths to Stabilisation

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CONCLUSIONS

Implications of the Climate Change discussion for Turkish Economy in general and the Electrical Power Industry in particular
Likely Scenarios

- A carbon tax may be sought by Western countries asking the power generators to pay for each tonne of CO2 emitted. This could be as high as $30. It would triple the cost of coal. This may mean the end of coal mining industry without zero-emission technologies.
- The western countries will ask the poorer countries to be a part of the carbon-minimisation program. So Turkey cannot watch from the stands. We will have to be part of the action. This means, for example, having to pay some international body $30 for every tonne of CO2 ($110 for each tonne of coal burned).
- This is only a start. Wide-ranging technological changes will have to take place if the world become serious in stabilising the CO2 emissions.
What is to be done?

1. Integrated modelling and assessment
2. Industry change and impact modelling and policy development
3. New technologies to minimise Emissions
4. Adapting to climate change
Integrated Modelling and Assessment

• The specific impact of climate change on Turkey:
  – will we get wetter or drier?
  – will we get warmer or cooler?
  – what will be the effect on our immediate neighborhood?

• To be able to form her own answers to the above questions, Turkey needs an independent capability to do the following:
  – Climate change modelling
  – Benchmarking against other models
  – Detailed modelling of local impact
  – Better data collection/interpretation
Impact Modelling and Policy Development

• Modelling socio-economic impact of climate change and associated government policies

• Impact models for individual industries, e.g., agriculture, mining, power generation, manufacturing, transportation, etc
Emission Minimising Technologies

• CO₂ sequestration (Carbon Capture and Storage) ?
• Nuclear Energy ?
• Emission-less electricity generation
  – Solar
  – Wind
• Transportation
  – Ethanol mixes and blends
  – Electric cars
• Energy conservation
  – Building and air-conditioning
  – Manufacturing
  – Heavy industries
Adapting to Climate Changes

- CO$_2$ extraction from the atmosphere
  - Bio-engineering?
- Upper atmosphere radiation shielding
- Increasing earth surface reflectivity in selected areas
- Other “Spaceship Earth” stuff

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We can take action

1. Integrated modelling and assessment
2. Industry change and impact modelling and policy development
3. New technologies to minimise Emissions
4. Adapting to climate change

New challenges for the humanity.
New technologies are needed.
Huge opportunities for the providers of solutions.
Turkey can watch this unfold or can try to be an active player.
Or forget it all