



**The Abdus Salam
International Centre for Theoretical Physics**



2138-31

**Joint ICTP-IAEA Workshop on Vulnerability of Energy Systems to
Climate Change and Extreme Events**

19 - 23 April 2010

**Status of energy installations and energy supply infrastructures in Madurai, India
and predicted impacts of extreme events**

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India*



About Madurai Kamaraj University . . .

- One of the leading universities in South India / Located at Madurai (750 acres)
- Named after the great veteran leader Mr.Kamaraj
- Established in the year 1966 / 18 Schools / 9 Science + 9 Arts
- Motto of the university / “To seek truth is knowledge”
- 'University with Potential for Excellence' by University Grants Commission (UGC)

Status of energy installations and energy supply infrastructures in Madurai, India and predicted impacts of extreme events



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India

- ➔ Single largest democratic country (28 states & 7 UTs) with second largest population (17% of world's population)
- ➔ 3rd largest consumer of coal (Coal reserve for 70 years only)
- ➔ 6th largest consumer of oil
- ➔ Only 0.8% of known oil and natural gas reserves
- ➔ Good potential and prospects for renewable energy



Indian Towns and their Population (2001)



Class	Population Range	No of Towns	% of Towns	Population (million)	% of Population
I	$\geq 100,000$	423	8.20	172.044	61.48
II	50,000 to 99,999	498	9.65	34.431	12.30
III	20,000 to 49,999	1386	26.86	41.974	15.00
IV	10,000 to 19,999	1560	30.23	22.603	8.08
V	5,000 to 9,999	1057	20.48	7.983	2.85
VI	$< 5,000$	237	4.59	0.801	0.29
All Classes (I -VI)		5,161	100.00	279.837	100.00





- India has 5,161 towns out of which 27 (existing 4 & proposed 23) are metropolitan cities, 423 are class- I, 498 are class –II, and the rest are 4240 below 50,000 (2001 Census)
- Slow growth of population in smaller towns and fast urbanization in larger cities
- Large cities are provider of major services and smaller towns are centres of development for surrounding rural area
- IT revolution has been one of the major influencing factors for energy demand

Energy consumption in India

India's per capita energy consumption remains low

	Energy consumption (kgoe)
India 2003	304
India 2032 (8% growth rate, BAU base case)	1240
World Average 2003	1688



India's Energy Policies: Scenarios Simulated by MARKAL (2001-2031)



- **Baseline:** Base year 2001

GDP growth 8%
Official demographic projections
IPCC emissions factors

- **S1:** New and renewable energy for power generation

- **S2:** Electricity for all by 2012

Decentralized renewable options
Efficient cook stoves

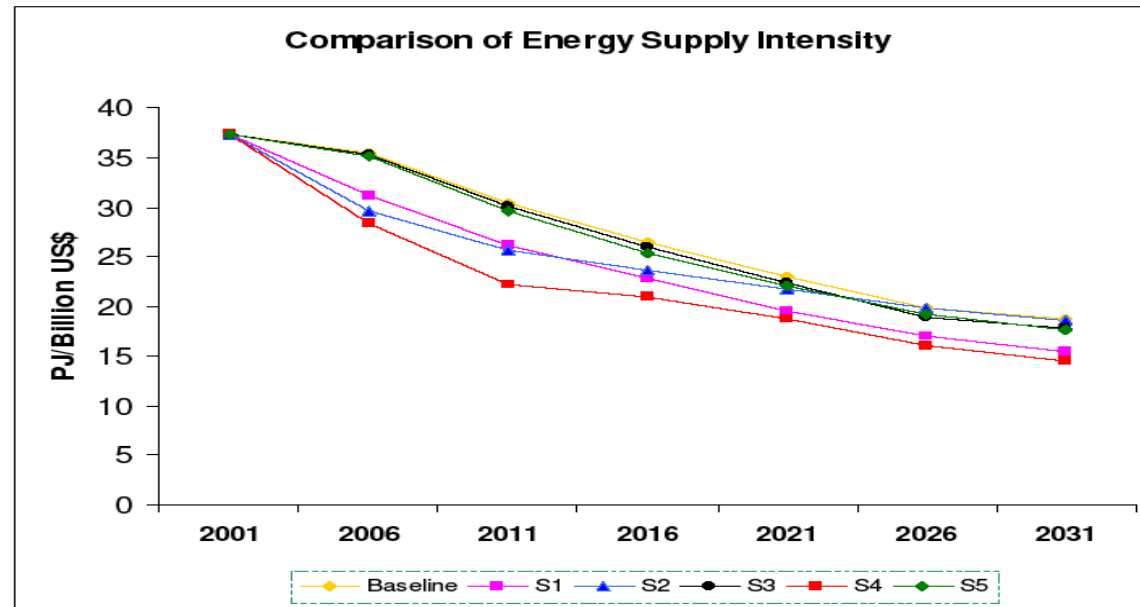
- **S3:** Encouragement of the mass transit system by improving the present infrastructure with an increase of 20%

Greater use of CNG in buses, taxis, 3-W vehicles

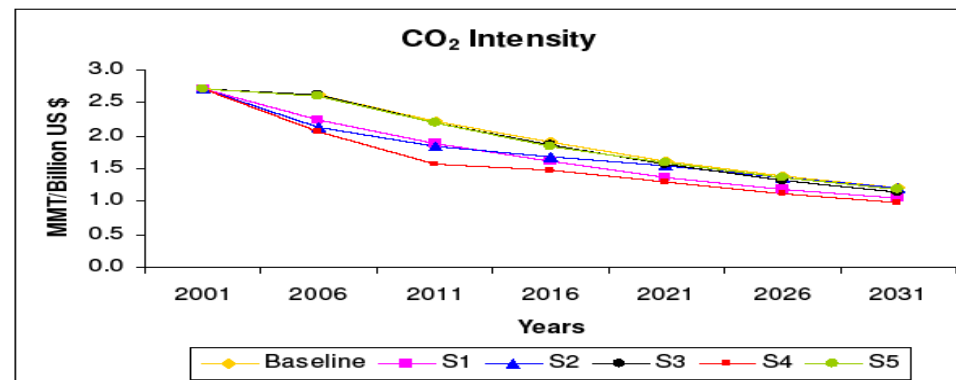
- **S4:** S1+S2+S3



- **S5:** Average annual GDP growth rate 6.7%



Change in India's CO₂ intensity as a result of Government policy initiatives



India's vulnerability to climate change – predicted change by 2050



Maximum temperature

- Increase by 2 to 4°C during 2050s in regions above 25°N

Monsoon Rainfall

- Marginal changes in monsoon months : Large changes during non-monsoon months

Number of rainy days

- Decrease in the number of rainy days over a major part of the country. More in western and central part (by more than 15 days) while near foothills of Himalayas (Uttaranchal) and in northeast India the number of rainy days may increase by 5-10 days





Extreme Rainfall events

- Overall increase in the rainy day intensity by 1-4 mm/day except for small areas in northwest India

Cyclonic storms

- Increase in frequency and intensity of cyclonic storms is projected



India's vulnerability to extreme events

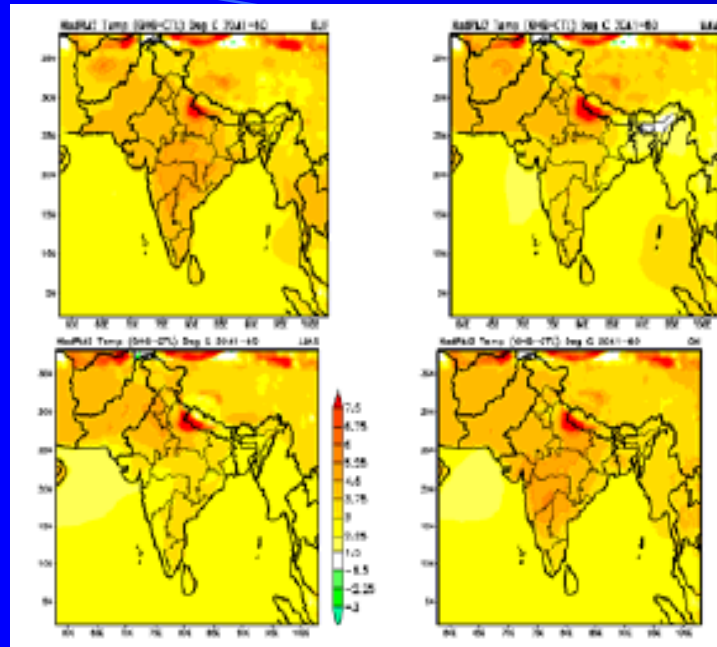


- Heavily populated regions such as coastal areas are exposed to climatic extremes and large falls in sown areas in arid and semi-arid zones, of which nearly two-thirds are drought-prone
- Large areas in Rajasthan, Andhra Pradesh, Gujarat, and Maharashtra and comparatively small areas in Karnataka, Orissa, Madhya Pradesh, Tamil Nadu, Bihar, West Bengal, and Uttar Pradesh are frequented by drought
- About 40 million hectares of land is flood-prone, including most of the river basins in the north and the north-eastern belt that affects about 30 million people on an average each year

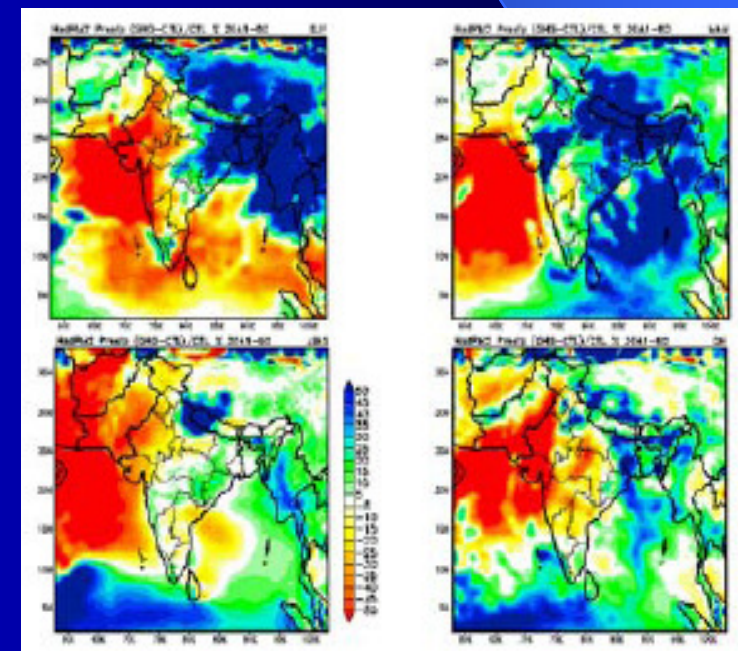




Projections of seasonal precipitation for the period 2041-60, based on the regional climate model HadRM2



Temperature



Precipitation

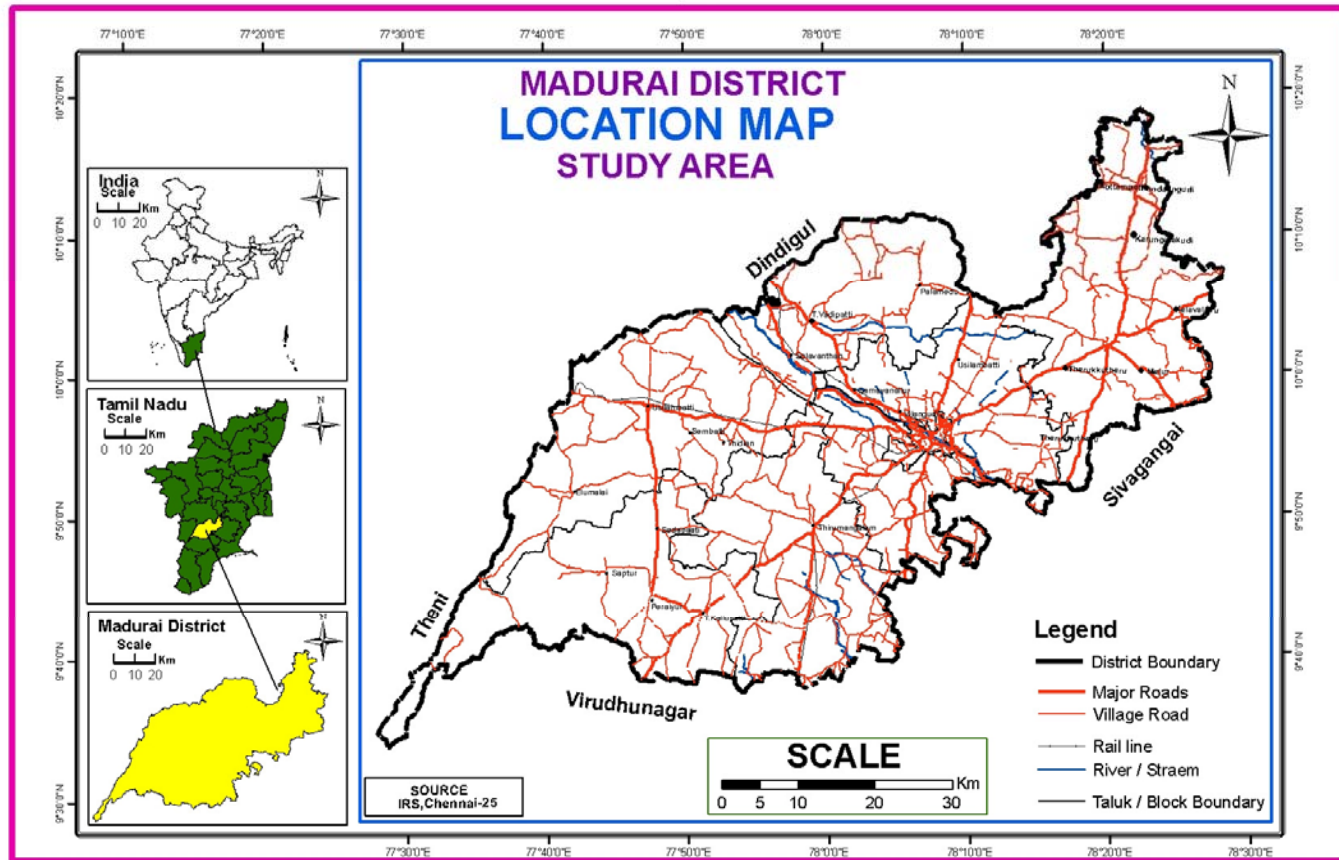


Source: India NATCOM

Tamil Nadu / Madurai



Map 2.1



Tamil Nadu / Madurai



✦ Eleventh largest state by area & southern most state of India

✦ One of the most urbanized states & seventh most populous state in India

Area	1,30,058 Sq.Km.
Population	62 million as per census 2001
Per capita energy consumption	976.8 KWh
Temperature	25 to 40 °C
Annual rain fall	945 mm
	(48% NE & 32% SW monsoon)

✦ Most of the criteria air pollutants (Sulphur dioxide, nitrogen oxides, carbon monoxide, suspended particulate matter and lead) cross the permissible limits set by CPCB at all the Corporations of Tamil Nadu

✦ Third largest coast line in India (910 Km) and so Indian ocean Tsunami caused 7793 direct deaths



One of the vulnerable states to climate change in India

Renewable Energy generation and utilisation in TN



- ❁ An installed capacity of 4790 MW from renewable sources as on 31.3.2009 against country's installed capacity of 14485 MW, which is about 33%.
- ❁ **Wind power** : Tamil Nadu is No. 1 in India with an installed capacity of 4287 MW as on 31.3.2009, which is about 44% of the total installed capacity in India. The private investment in wind power exceeds Rs.18200 crores. The power generation has exceeded 40 billion units (cumulative).
- ❁ **Solar power** : Installed capacity of 22 MW as on 31.03.2009.
- ❁ **Cogeneration & biomass** : Tamil Nadu is a pioneer in introducing cogeneration in sugar mills and continues to lead with installed capacity of 366 MW of which exportable surplus is 266 MW, which is about 250% of installed capacity in India. The installed capacity from biomass is 147.5 MW. (includes waste to energy projects)
- ❁ **Hydro power** : Under small hydro project implemented by TNEB directly, Tamil Nadu has an installed capacity of 89.7 MW as on 31.3.2009.





Wind mills at Muppandal, Tamil Nadu

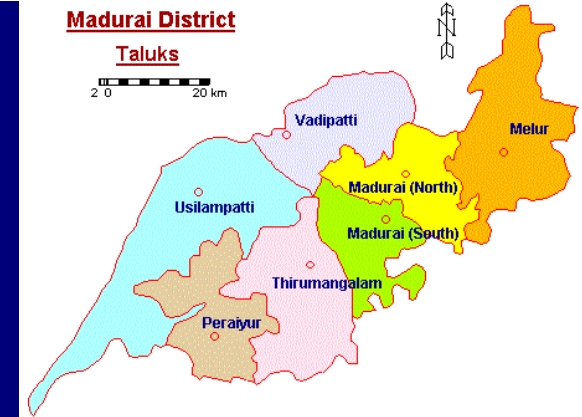


Wind mills at Aaralvaimozhi, Tamil Nadu

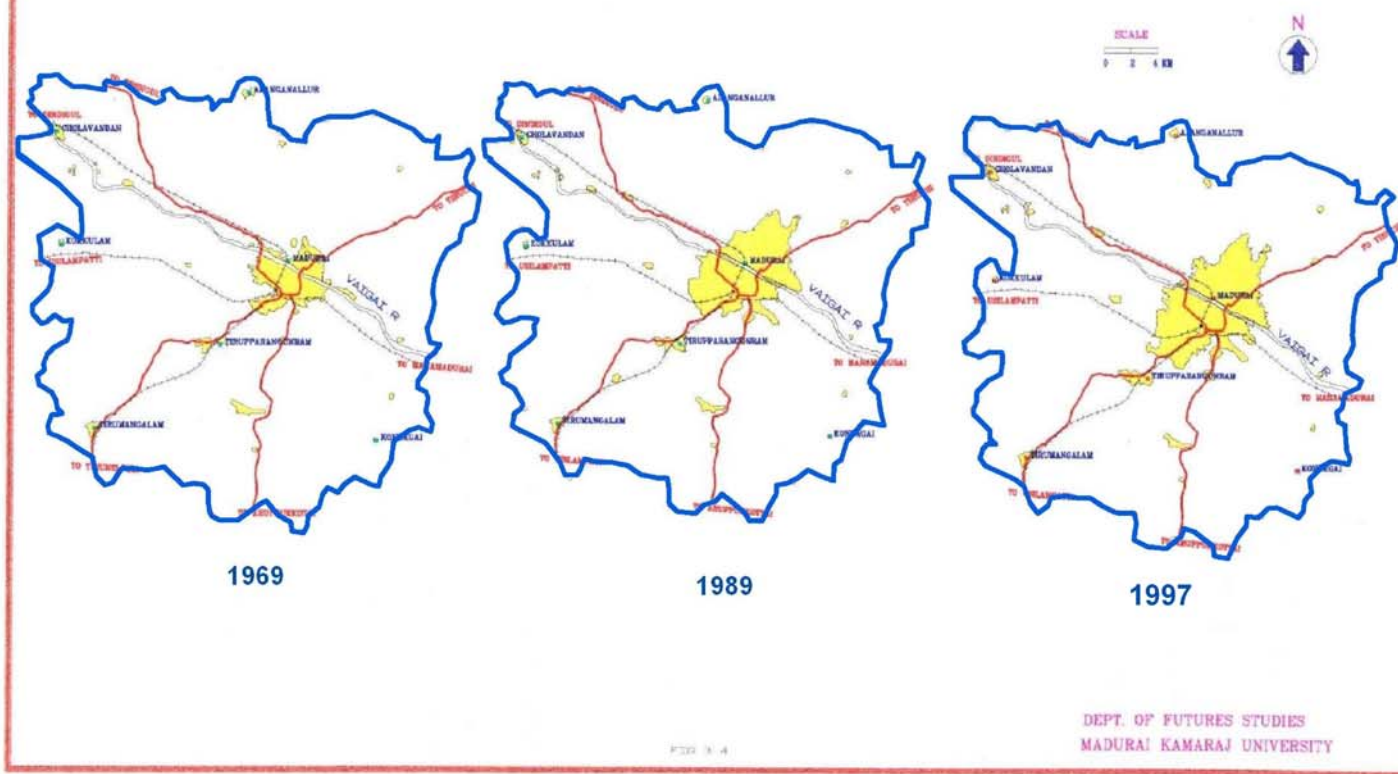


Madurai city

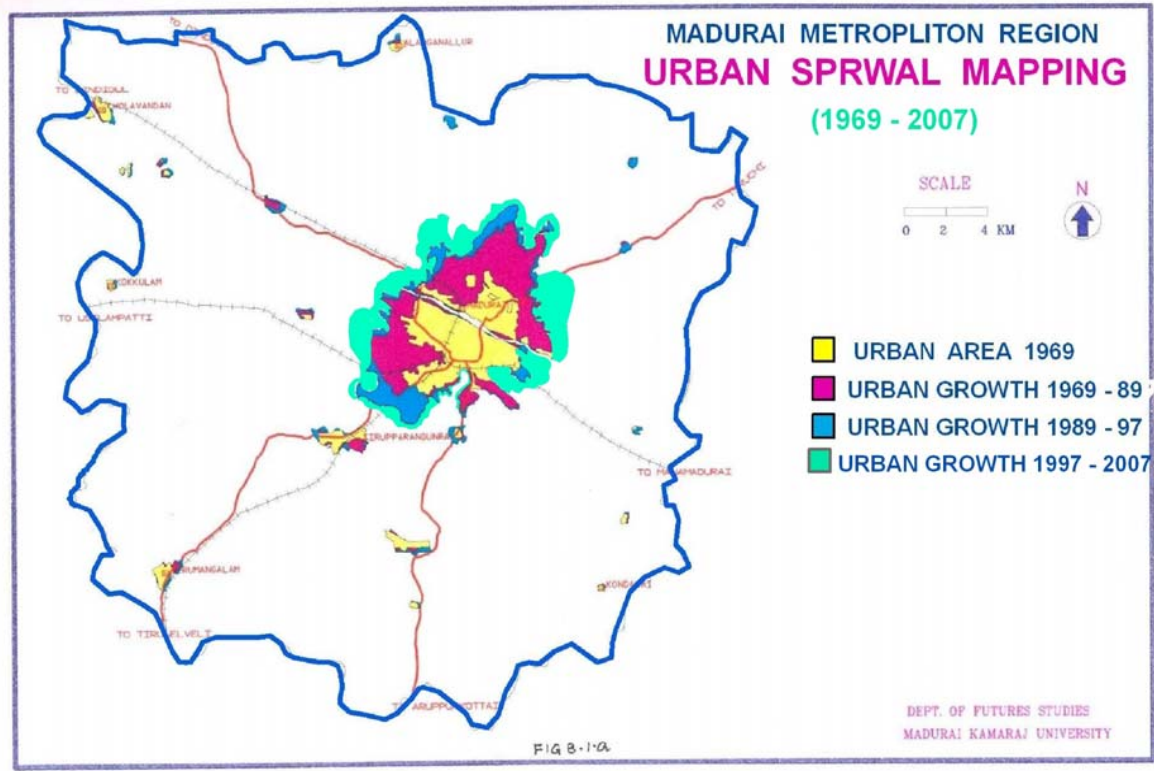
- ➔ Cultural & Political capital of Tamil Nadu
- ➔ River Vaigai flows in the centre of the city
- ➔ Geographical location : $9^{\circ} 54' N$; $78^{\circ} 06' E$
- ➔ Area : 51.96 Sq. Km.
- ➔ Population : 9,22,913
- ➔ Population density : 213 persons / hectare
- ➔ Population density (Vaigai banks and around Temple) : 998 persons / hectare
- ➔ Floating population : 2.10 lakh / day



URBAN SPRAWL DYNAMICS OF MADURAI CITY 1969 - 97



MADURAI METROPLITON REGION URBAN SPRWAL MAPPING (1969 - 2007)



Possible extreme events in Madurai city



Flood

Heavy rain in catchments

Flood threat in river Vaigai (atleast once in a decade with severe effects)

River banks, roads & bridges

Drought

Drought-prone city (in Tamil Nadu)

Increase in atmospheric temperature / Water scarcity

Earthquake

Expected due to overexploitation of granites in the outskirts

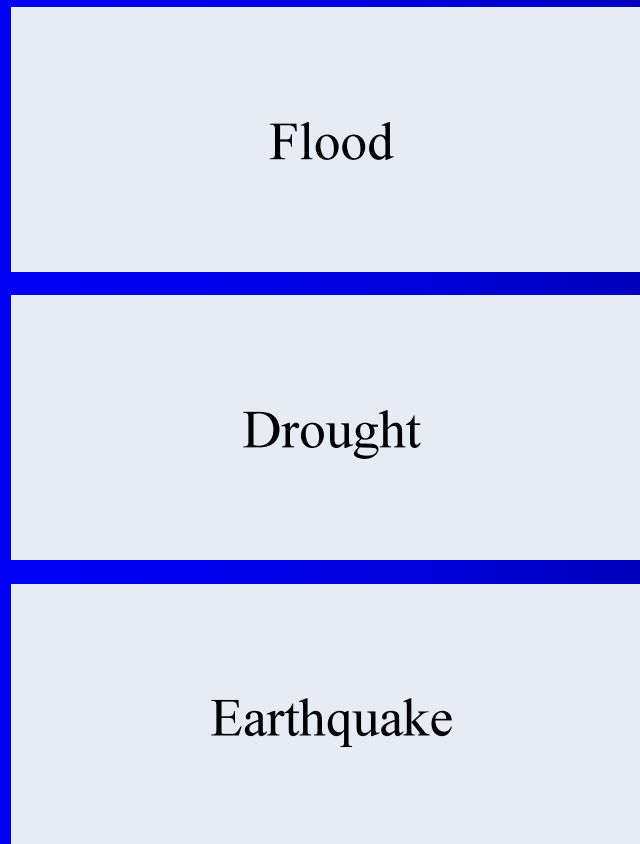
Structural collapse, roads & bridges



Potential Impacts



Impacted Sectors



- Transportation
- Environment
- Energy
- Meteorology
- Infrastructure
- Economy

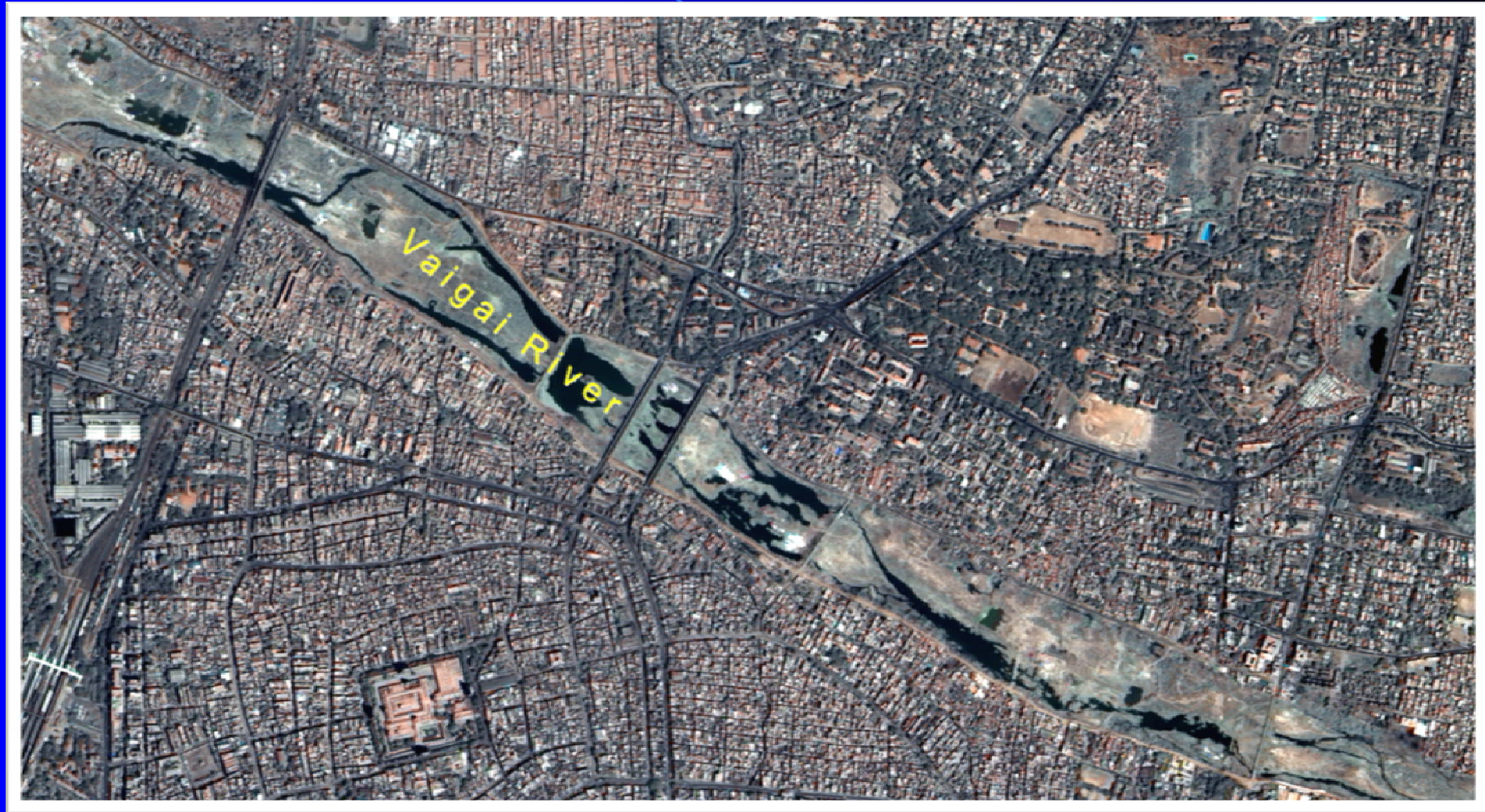




Road Network Development



MADURAI CORPORATION: VAIGAI RIVER



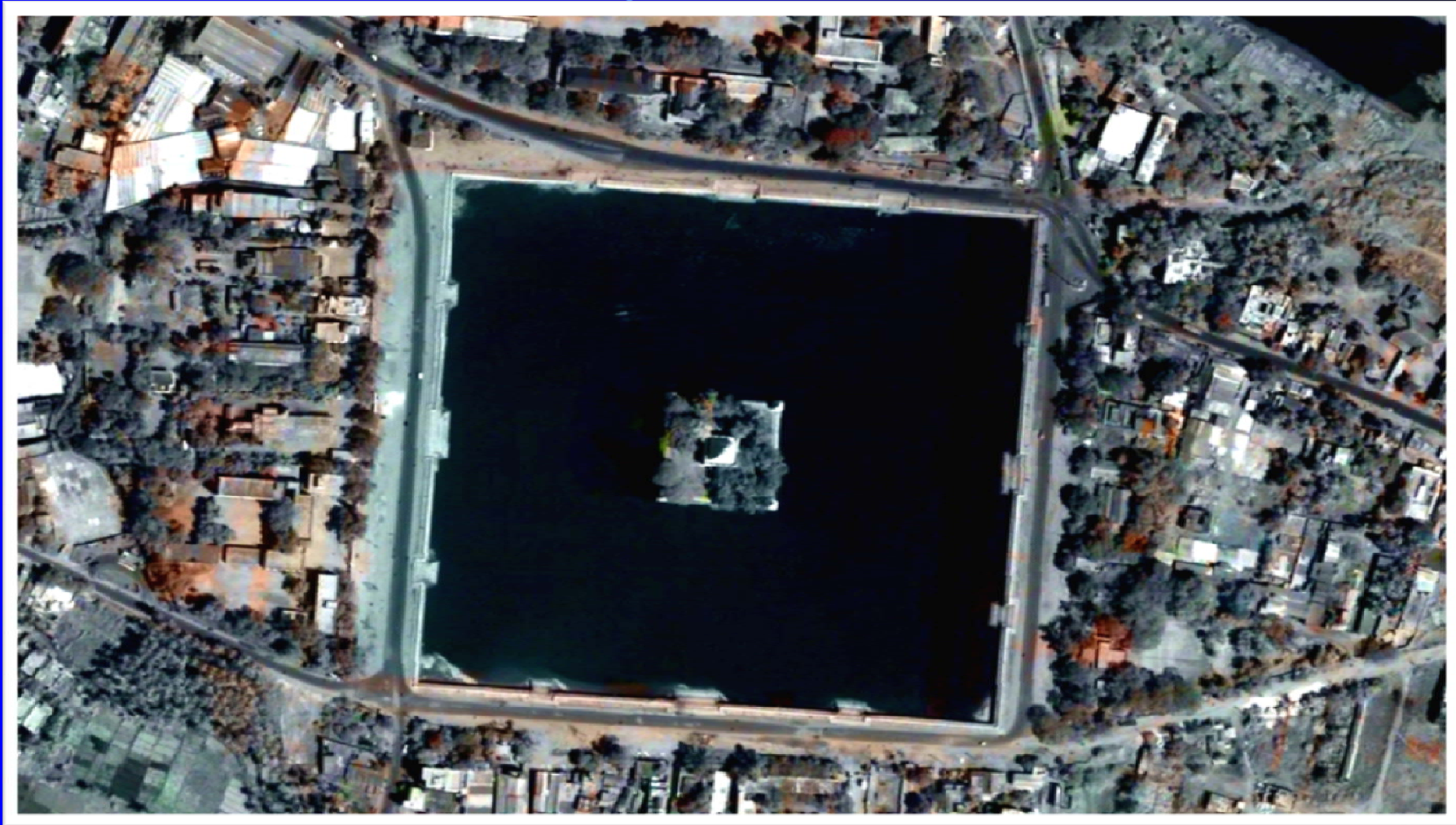
MADURAI DISTRICT-ROAD NETWORK



MADURAI CORPORATION: SRI MEENACHI AMMAN TEMPLE



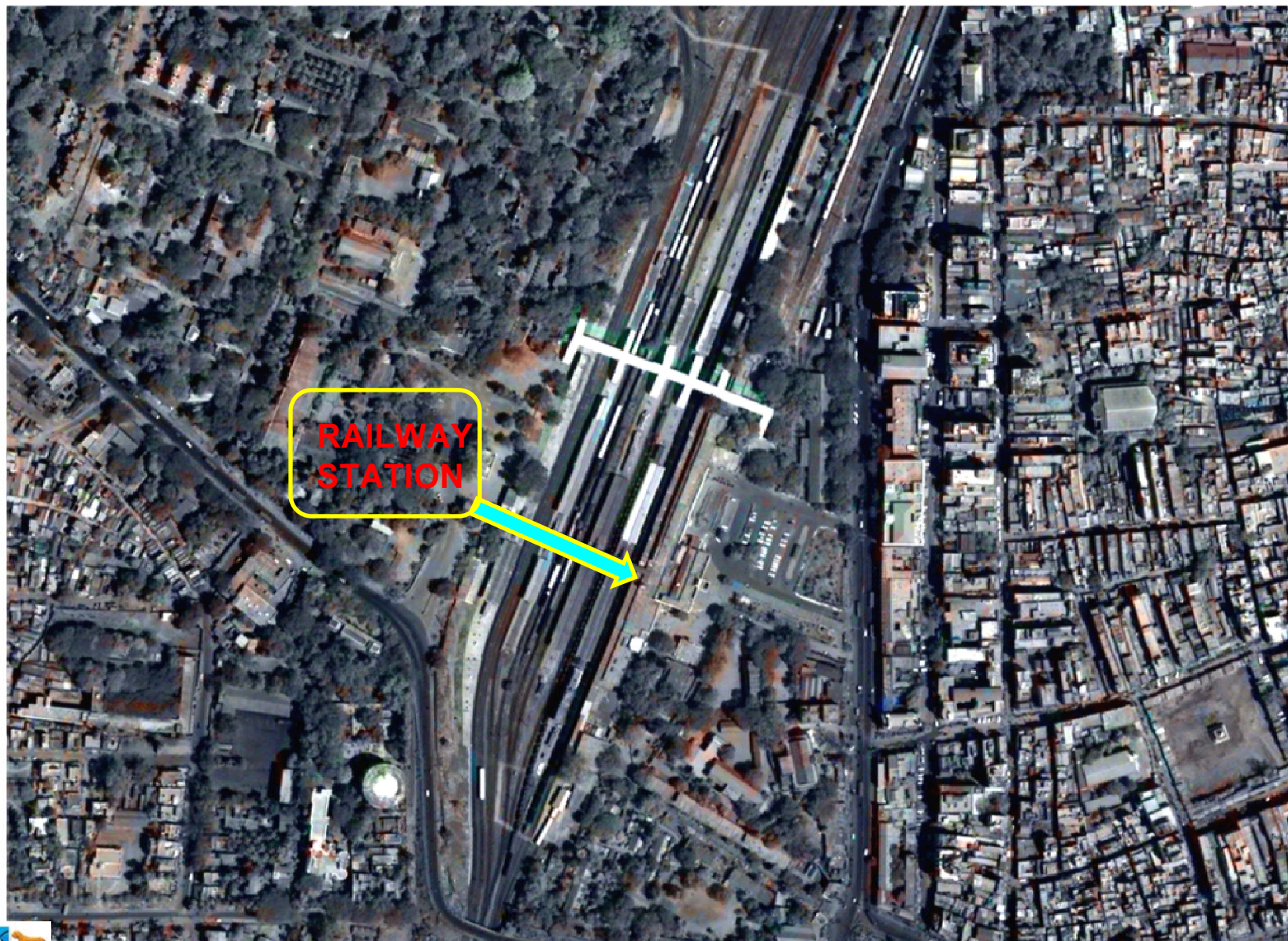
MADURAI CORPORATION: THEPPA KULAM



MADURAI CORPORATION: NAYAKAR MAHAL



MADURAI CORPORATION: RAILWAY STATION



MADURAI CORPORATION: TVS NAGAR



MADURAI DISTRICT-INDUSTRIAL AREA



Area available for road and circulation

18.17%

Total length of roads

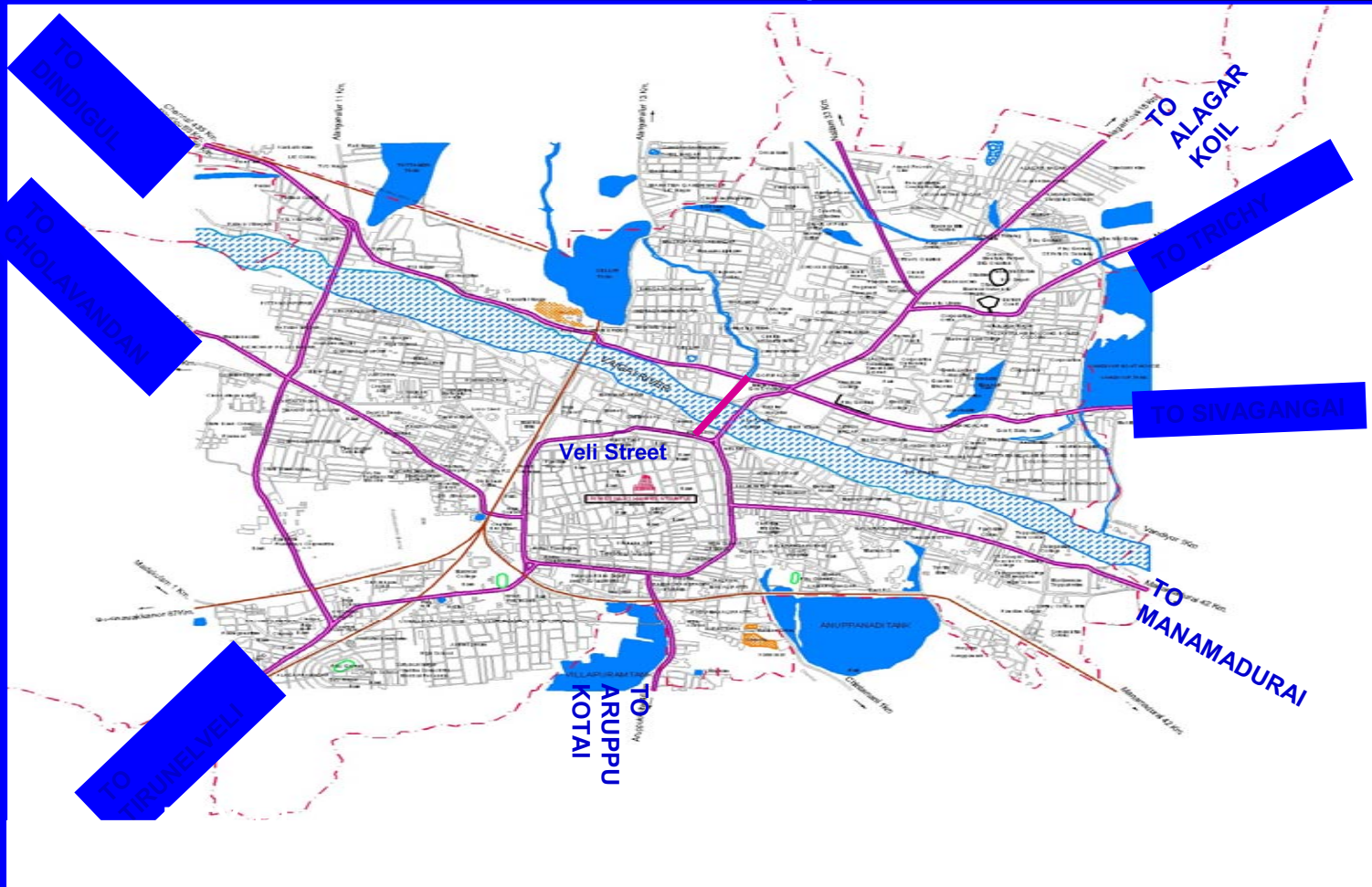
615.3 Kms

Municipal roads

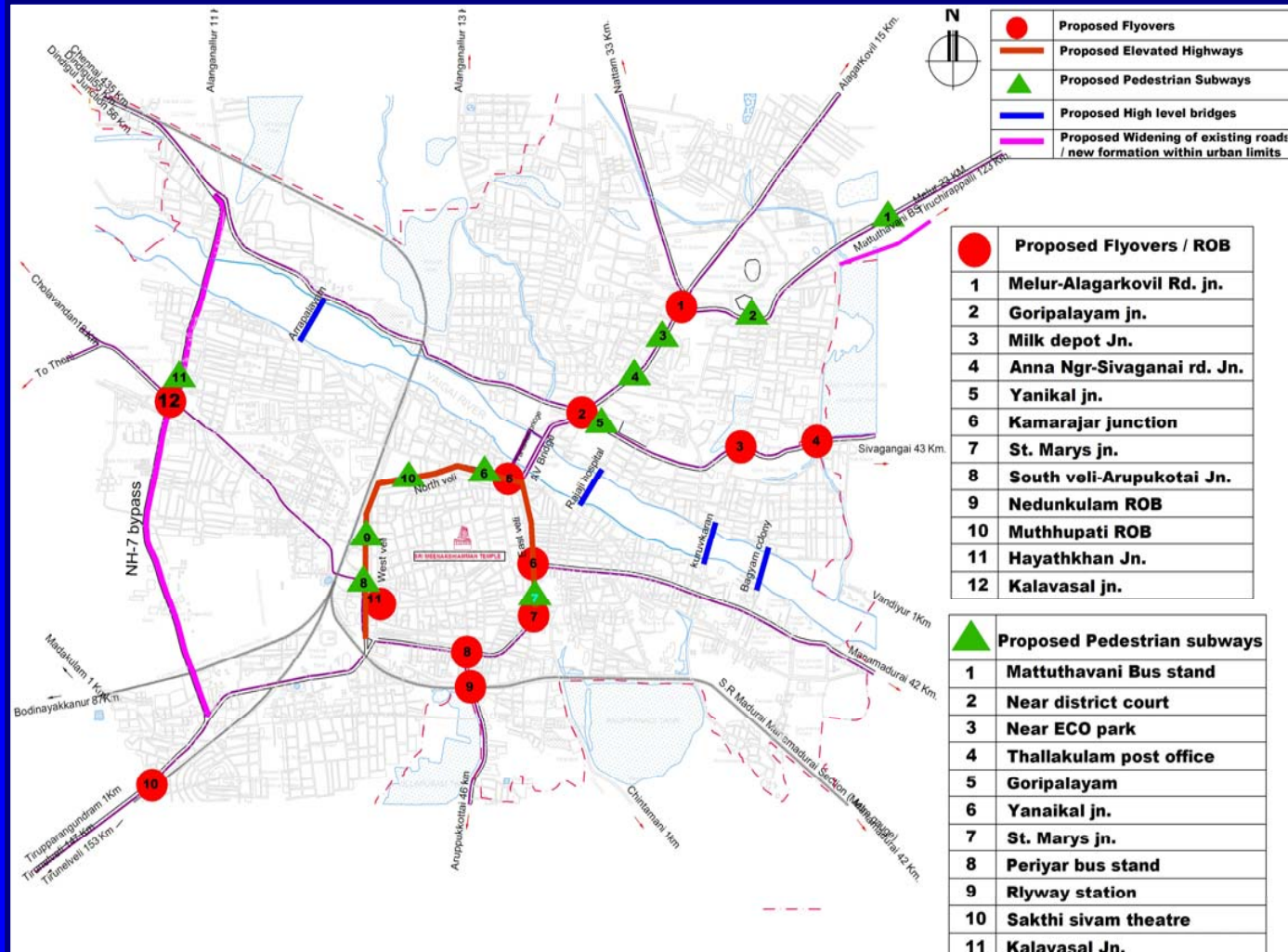
581.31 Kms

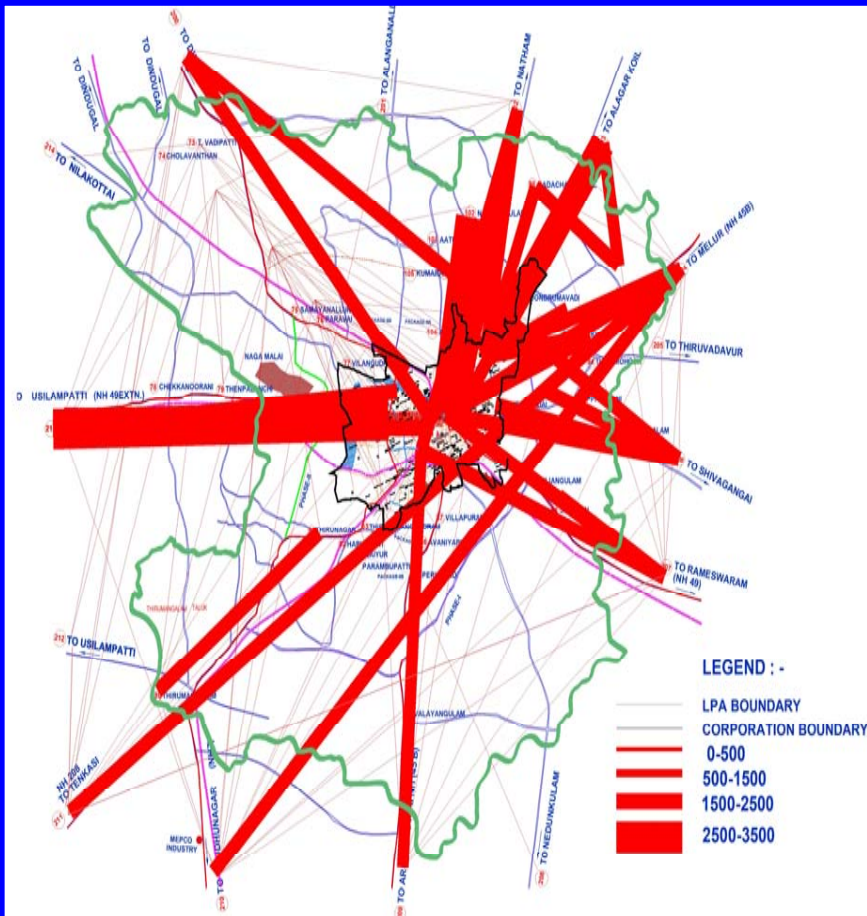
Highways roads

34.0 Kms

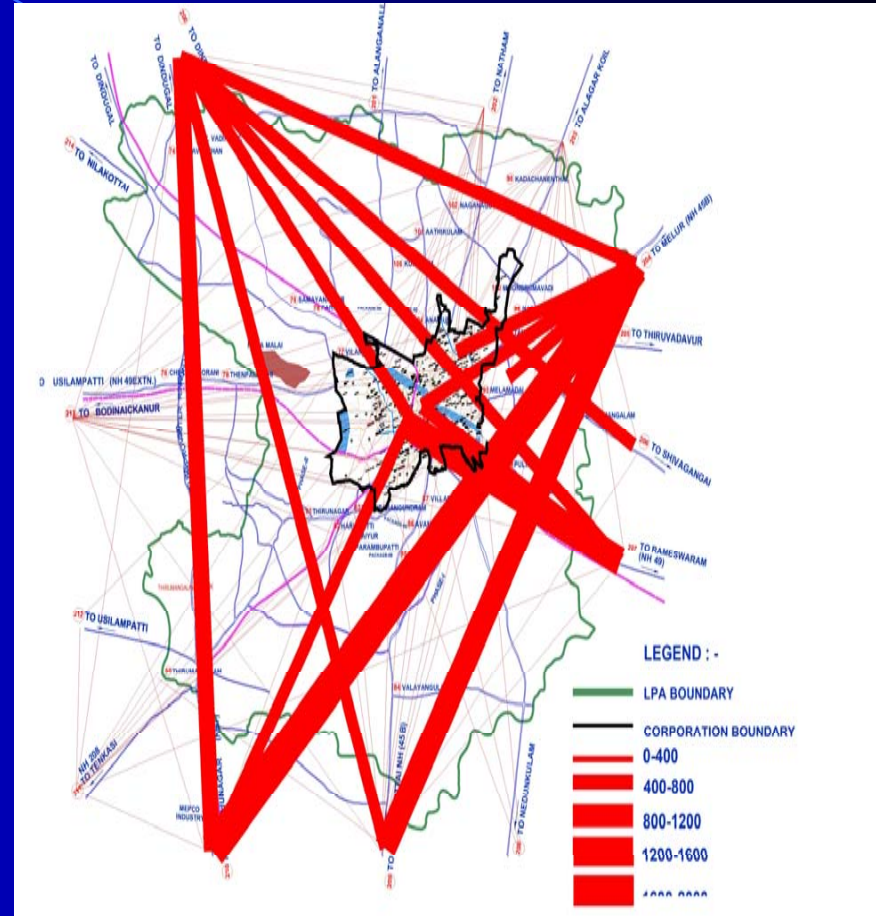


KEY PLAN SHOWING THE LOCATIONS OF FLYOVERS, ROB, PED.SUBWAYS, BRIDGES AND ELEVATED ROADS





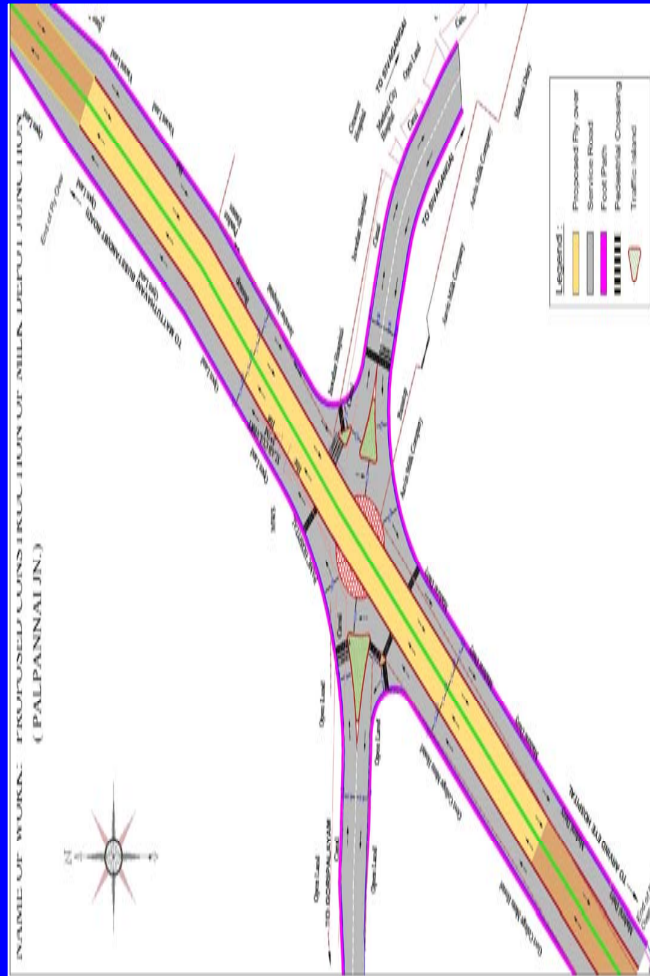
Passenger traffic movement



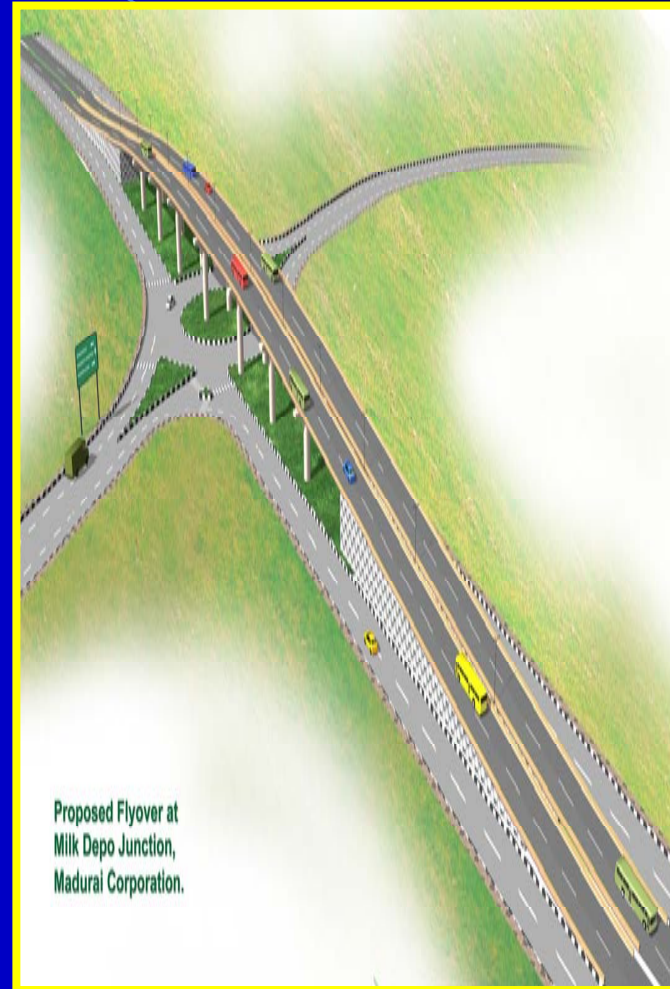
Goods traffic movement



Proposed flyover (Useful during flood)



Proposed flyover (Useful during flood)





- ➔ Networks are essential for quality of life / Commerce & Trade / Defense / Emergency response in event of disaster
- ➔ Better roads and infrastructure reduce fuel consumption and hence environmental pollution

Performance-based design (PBD)

- ▣ New development in the design of civil infrastructure for extreme events is necessitated
- ▣ Life-safety is no longer sole requirement
- ▣ Preserving functionality and minimizing economic loss are additional criteria
- ▣ Performance expectations increase with importance of infrastructure; but may decrease with increasing size or rarity of event
- ▣ Powerful tool for mitigation, pre-event planning and emergency response

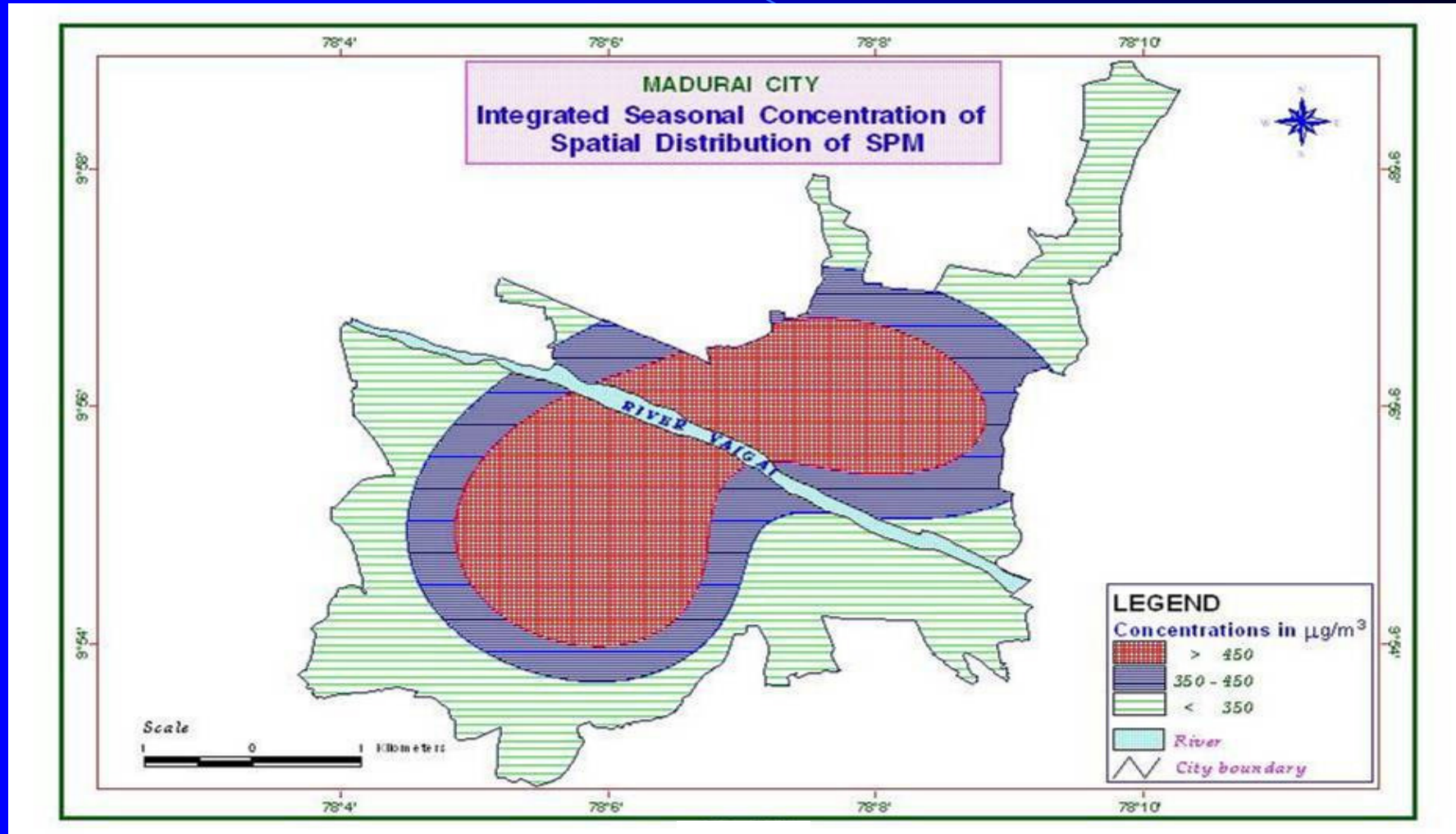




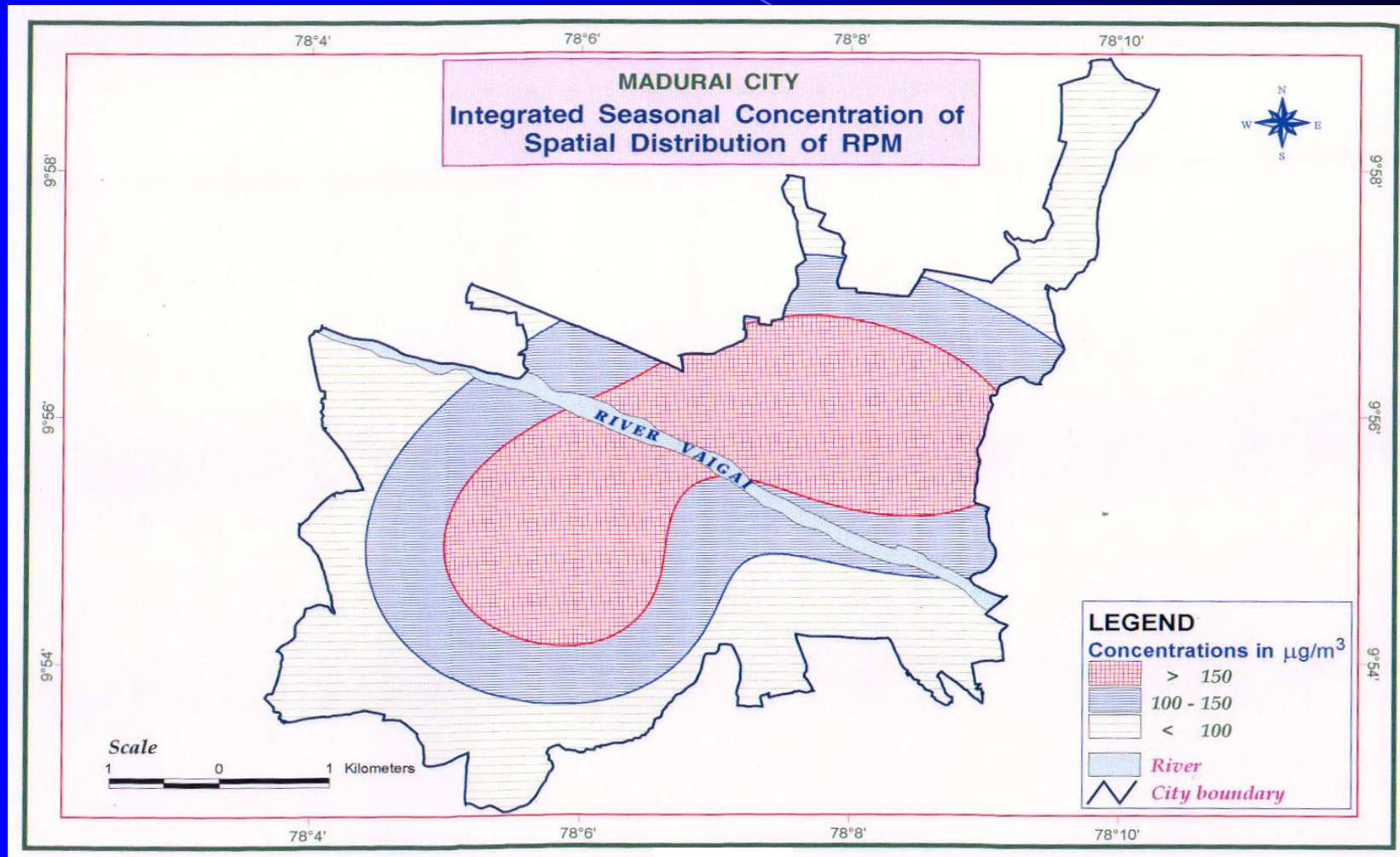
Environmental Protection



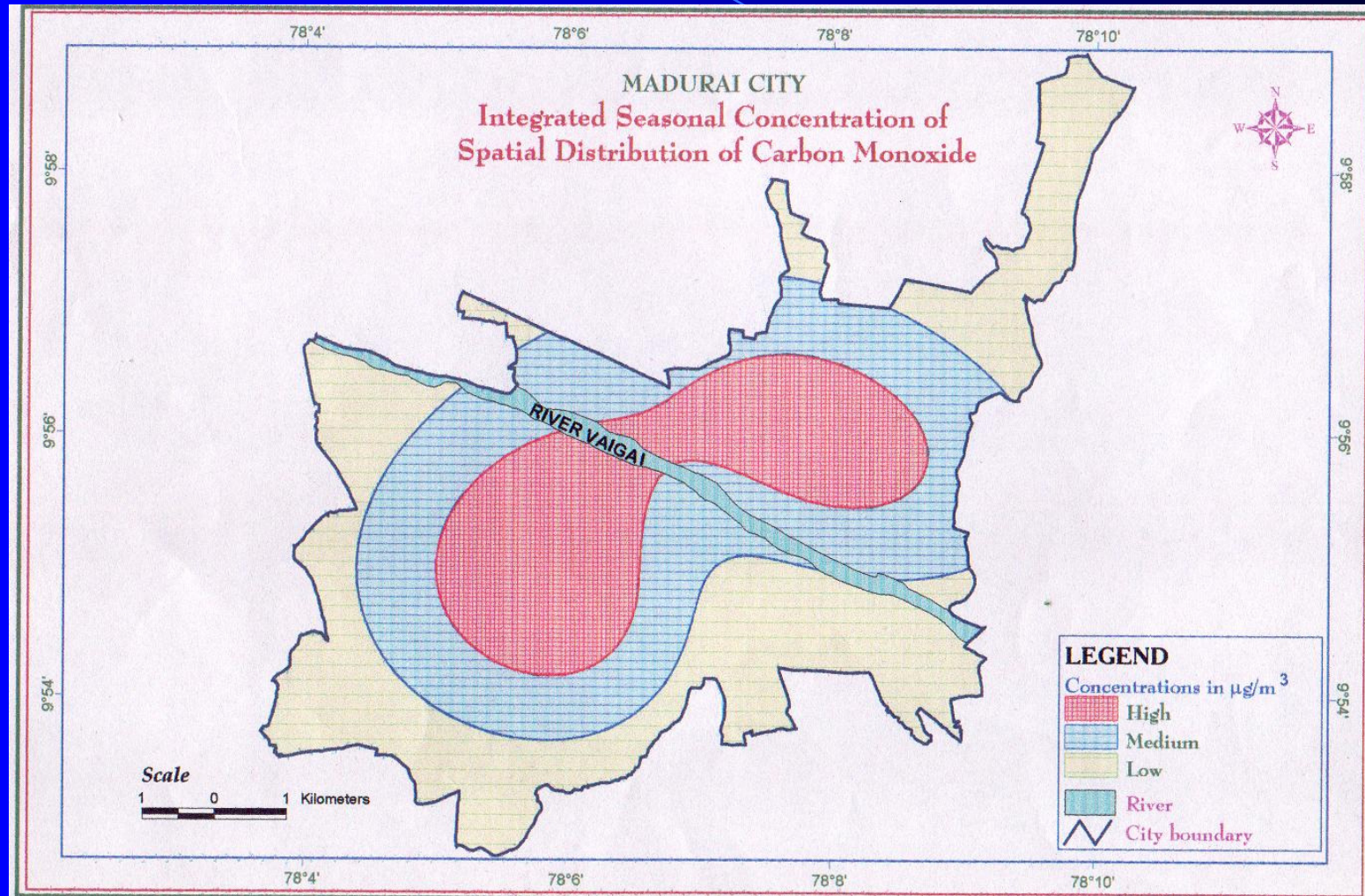
Air pollutants emitted during fuel combustion (SPM < 100 μ)



Air pollutants emitted during fuel combustion (RPM <math>< 10 \mu</math>)



Air pollutants emitted during fuel combustion (CO)



Proposed plan to reduce air pollution in Madurai city



Shifting of markets and truck terminals are required and this process shall be one of the ways to reduce the emission loads of air pollutants

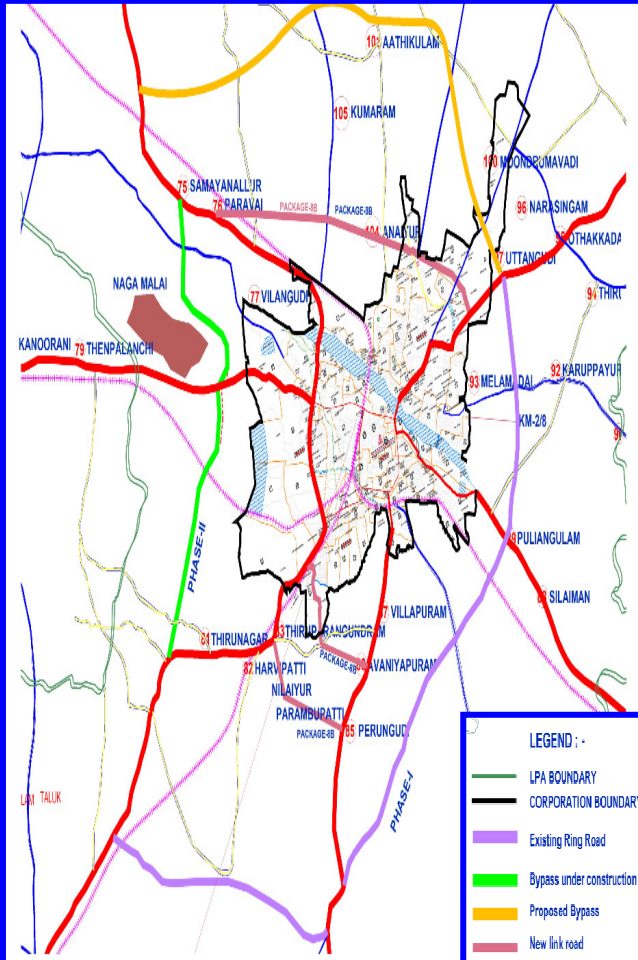
(Proposed plan is enclosed)



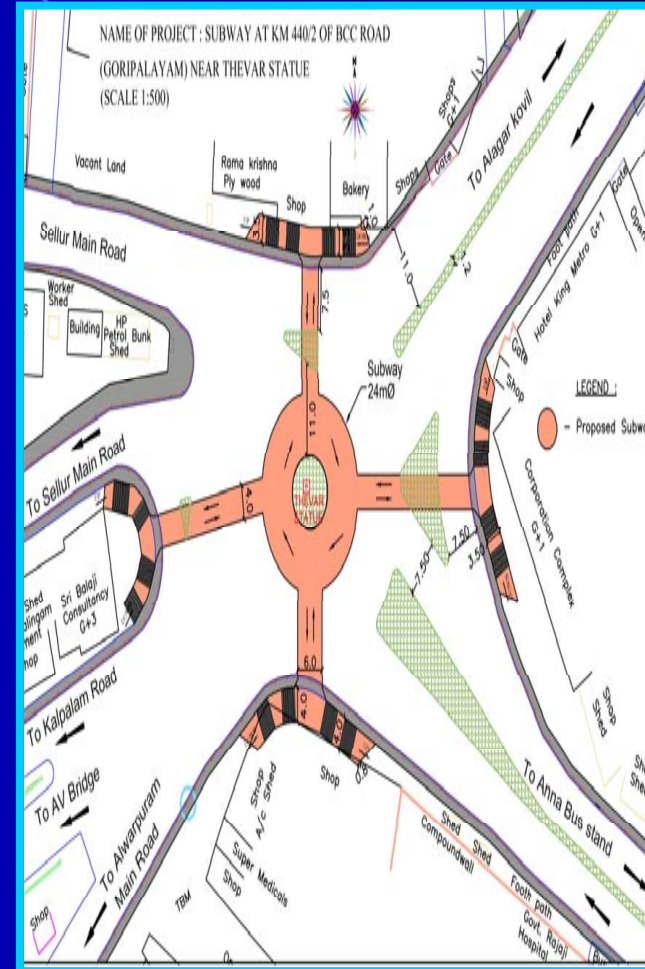
The highest emission in the city is at Goripalayam and one of the plans to reduce the levels of air pollutants is the construction of pedestrian subway

(Proposed plan is enclosed)





Proposed plan for Shifting of markets / truck stations



Proposed plan for Construction of pedestrian subway





Energy (Conventional & Renewable)



Potential and utilization of renewable energies in Madurai city



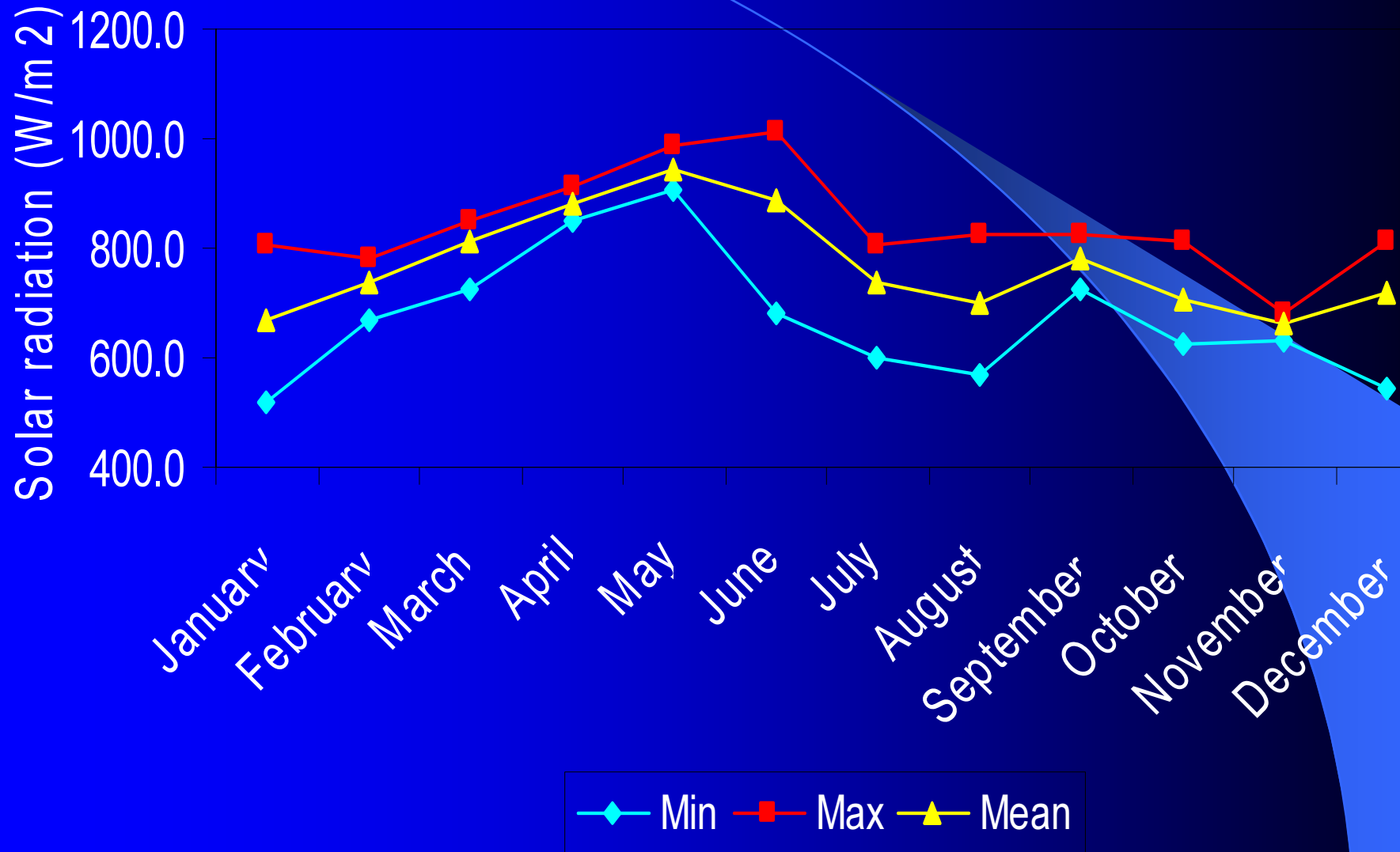
Potential for renewable energies

- Good potential for fostering renewable technology
- Solar thermal & Solar electrical technology in Madurai city
- Wind technology in Madurai region

Utilization of renewable gadgets

- Solar PV home lighting / street lighting systems
- Solar water heating systems / Solar arrays
- Solar hot air systems
- Solar cooking systems
- Solar steam generating systems

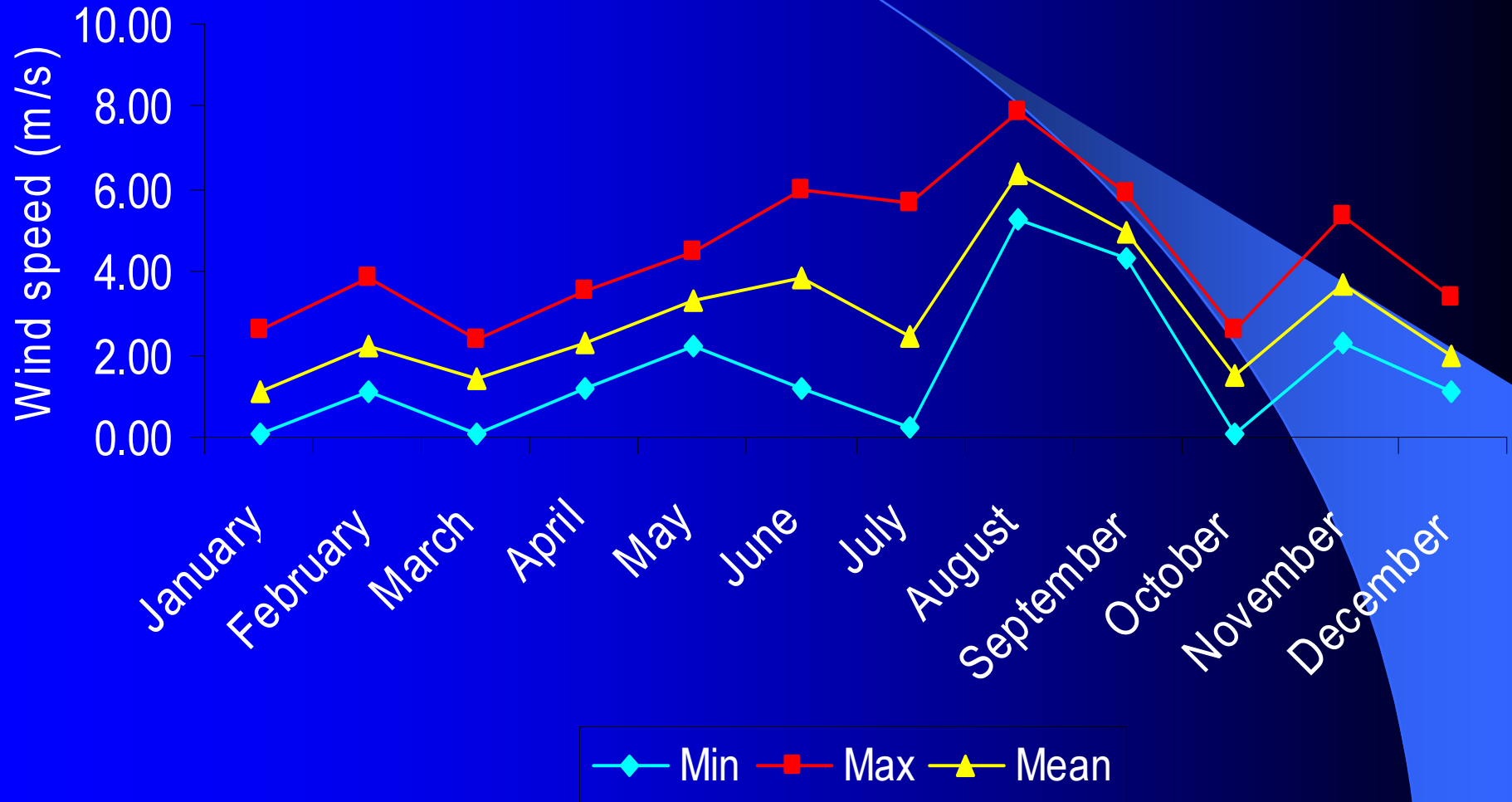
Solar potential in Madurai city



More than sufficient for operating solar thermal and electrical gadgets



Wind potential in Madurai city



Not sufficient for wind power generation

Wind potential at 40 Km away from Madurai



Station	Elevation	Annual mean wind speed (kmph)	Annual mean wind power density (w/m^2)	Annual mean wind power density (w/m^2)
		Measured at 20/25 m	Measured at 20/25 m	Extrapolated at 50 m
Andipatti	320	19.00	266	346
Meenakshi puram	290	16.40	224	334



Hydro power (at 69 Km away from Madurai)



- Location :

Built across Vaigai river / 69 Km from Madurai



- Power generation :

2 No. of 2.5 MW Periyar-Vaigai-4 small Hydro electric Project for a Grid connected system



Existing renewable systems in Madurai city



Existing solar thermal systems

➤	Solar water heating systems (100 lpd /125 lpd)	130 No.
➤	Solar arrays (1000 lpd)	112 No.
➤	Solar drying system (100 sq.meter)	004 No.
➤	Solar cookers (Box cooker)	112 No.
➤	Solar community cooking system	003 No.
➤	Solar steam generating system	001 No.

Existing solar electric (PV) systems

Homelights

●	18 W panel with one light	222 No.
●	34 W panel with 2 lights	113 No.
●	34 W panel with 1 light and 1 fan	104 No.
●	74 W panel with 2 lights and 1 fan	106 No.
●	74 W panel with 4 lights	108 No.



Existing renewable systems in Madurai city (Cont...)



Existing solar street lights

74 W (automatic on and off)

226 No.

Existing solar electric systems

- Solar power pack for lighting 1KWp (Office) 04 No.
- Solar power plant 5kW (Educational institution) 03 No.
- Solar illuminated hoardings 1KWp 02 No.
- Solar road blinkers 2080 No.



Existing bio-energy based systems

- Biogas systems for domestic cooking 12 No.
- Biogasifier (6 KWe) 01 No.



Source : Tamil Nadu Energy Development Agency

Proposed renewable systems in Madurai city



Proposed areas of applications

☀️	Community cooking systems (for noon meal programme)	42 No.
☀️	Drying systems (for drying paddy & edible products)	24 No.
☀️	74 W (automatic on and off)	120 No.
☀️	Solar power plant 1kW (Educational institution)	08 No.
☀️	Biogas plants (Using market wastes)	01 No.
☀️	Biogasifier (24 KWe)	02 No.



Energy supply to Madurai city



Energy usage in Madurai city

Thermal energy	LPG / Kerosene / Fuel wood / Cowdung cake
Electric energy	Thermal power station (Coal and Lignite based)

Thermal power plant (Thoothukkudi)

◆ Location:	Southern part of Tamil Nadu
◆ Fuel:	Coal
◆ Power production :	Five units of 220 MW each
◆	50 million units of energy daily
◆ Feeding capacity:	1/3 of the power of Tamil Nadu



Energy supply to Madurai city (Cont...)

Thermal power plant (Neyveli)

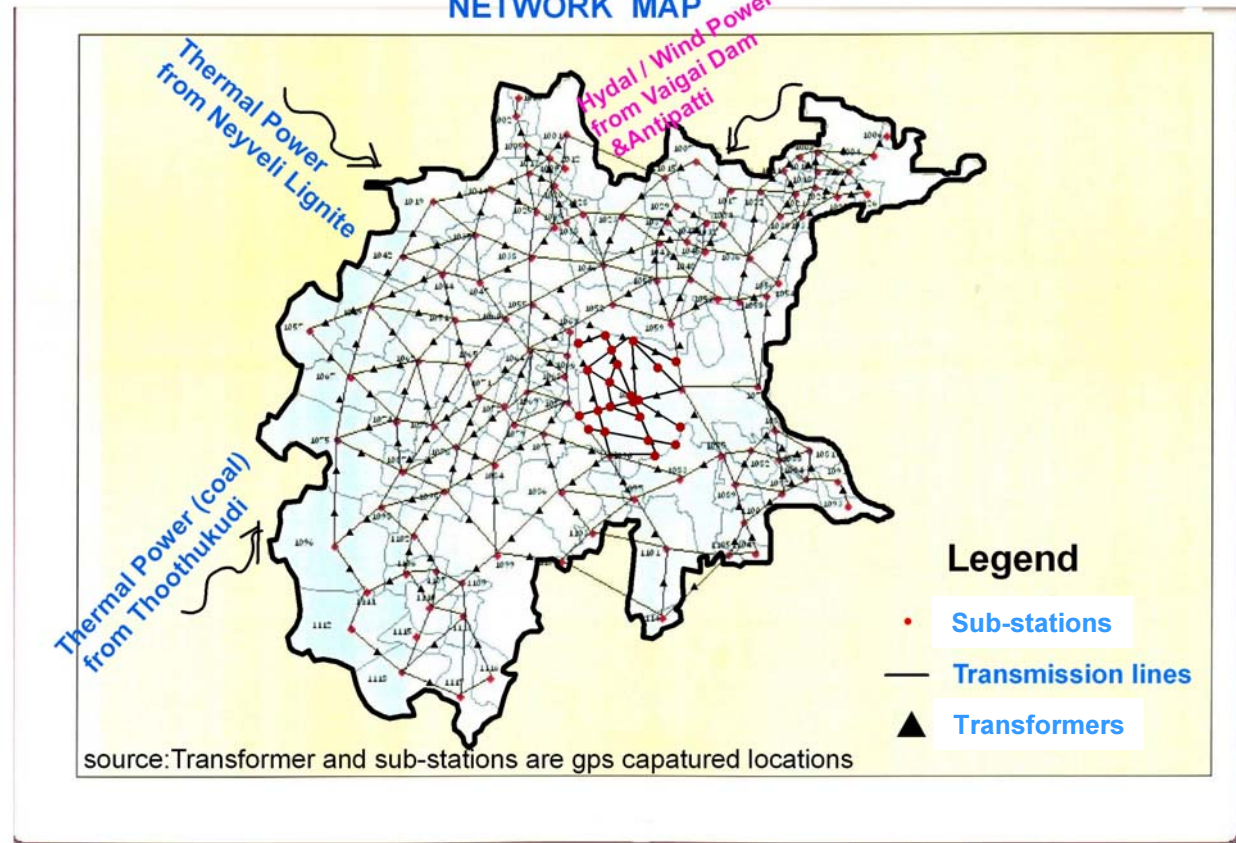
- Lignite mining (Open pit mining / 24 million tons per year)
- Location : Northern part of Tamil Nadu
- Fuel: lignite
- Power production : 2490 MW / year
50 million units of energy daily
- Feeding capacity 1167 MW to Tamil Nadu & remaining to neighbouring states

Hydro and wind power stations

- Vaigai dam (Hydro power station)
- Andipatti (Wind power station)



MADURAI METROPOLITAN REGION ELECTRICAL SOURCE TRANSMISSION NETWORK MAP



Flood



Frequency

Once in a decade (Average)

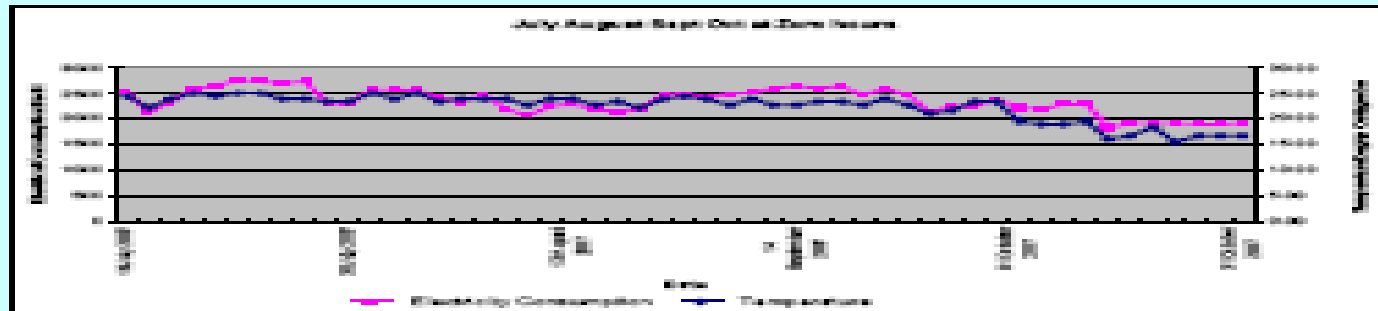
Drought



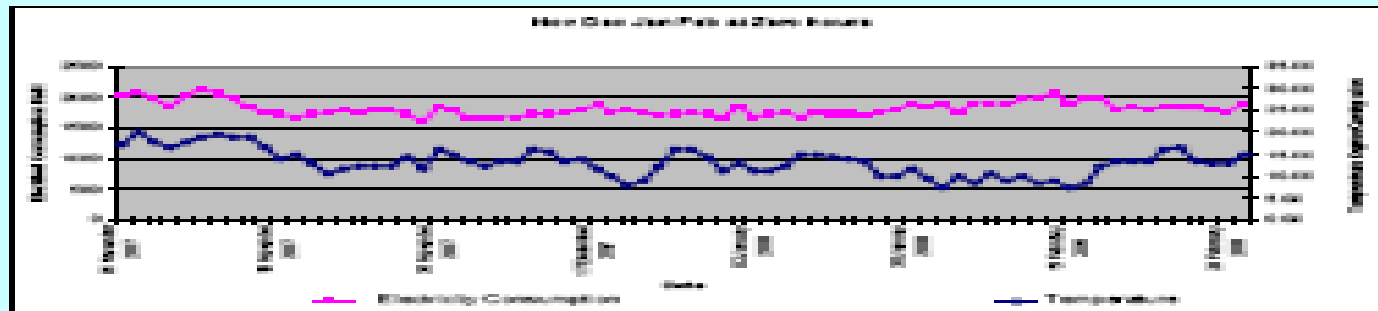
Frequency

Once in every three years (Average)

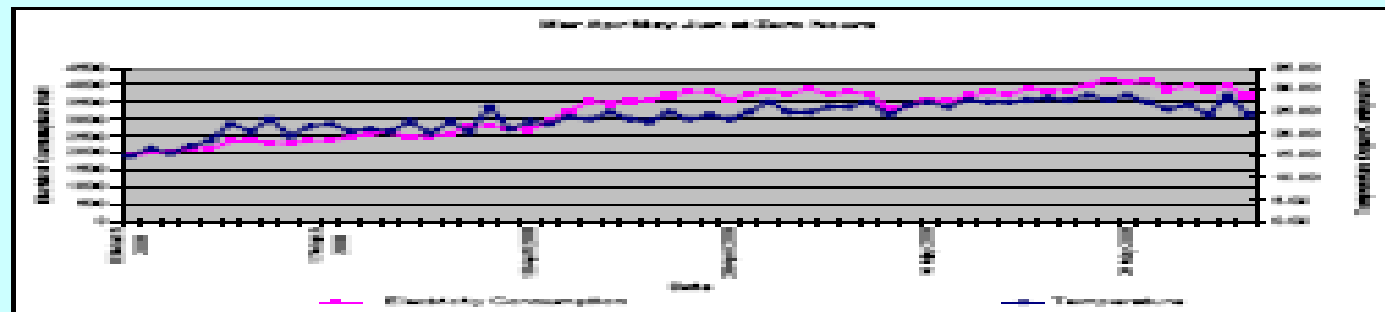
Emerging Findings: Temperature Effect



July-Aug-
Sept-Oct



Nov-Dec-
Jan-Feb



March-Apr-
May-June

- Electricity consumption could be well correlated with temperature changes
- Marked seasonality and periodicity in electricity demand



Exclusive ministry (MNRE)

- ◆ The Ministry of New and Renewable Energy (MNRE) is the nodal Ministry of the Government of India for all matters relating to new and renewable energy
- ◆ The broad aim of the Ministry is to develop and deploy new and renewable energy for supplementing the energy requirements of the country
- ◆ Achievements as on 31.12.2009

No.	Sources / Systems	Achievements during 2009-10 (upto 31.12.2009)	Cumulative Achievements (upto 31.12.2009)
1.	Wind Power	683.00 MW	10925.00 MW
2.	Small Hydro Power (up to 25 MW)	129.15 MW	2558.92 MW
3.	Solar Power	3.10 MW	6.00 MW
4.	Solar PV Power Plants and Street Lights	0.086 MWp	2.39 MWp
5.	SPV Home Lighting System	48 nos.	5,10,877 nos.
6.	Solar Lantern	58,064 nos.	7,67,350 nos.
7.	SPV Street Lighting System	2767 nos.	82,384 nos.
9.	SPV Pumps		7,247 nos.
10.	Solar Water Heating - Collector Area	0.35 Mln. sq.m.	3.25 Mln. sq.m.
11.	Solar Cookers	0.15 lakh	6.72 lakh

Regional Test Centre (Solar Thermal) Madurai

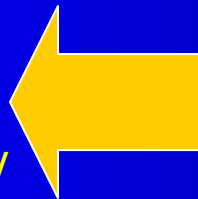
- ➔ One of the main charters of Ministry
- ➔ 5 Centres in India out of which this is the one and only Centre located in south India (at Madurai Kamaraj University)
- ➔ Provides test and referral facilities to the manufacturers / state nodal agencies / R&D organizations for the testing of Solar Thermal Systems
- ➔ Acts as testing centre for the Bureau of Indian Standards (BIS) for solar collectors and solar cookers
- ➔ Inspects, monitors and tests various solar devices on behalf of state nodal agencies / MNRE to ensure quality of products
- ➔ Organizes training programmes, business meets and offer technical back-up for potential users of solar thermal devices

Solar collectors used in Madurai city

- Flat plate collectors are widely used in fluid heating systems
- ISI marked collectors are used in Madurai city
- ISI marking laboratory is at Madurai Kamaraj University

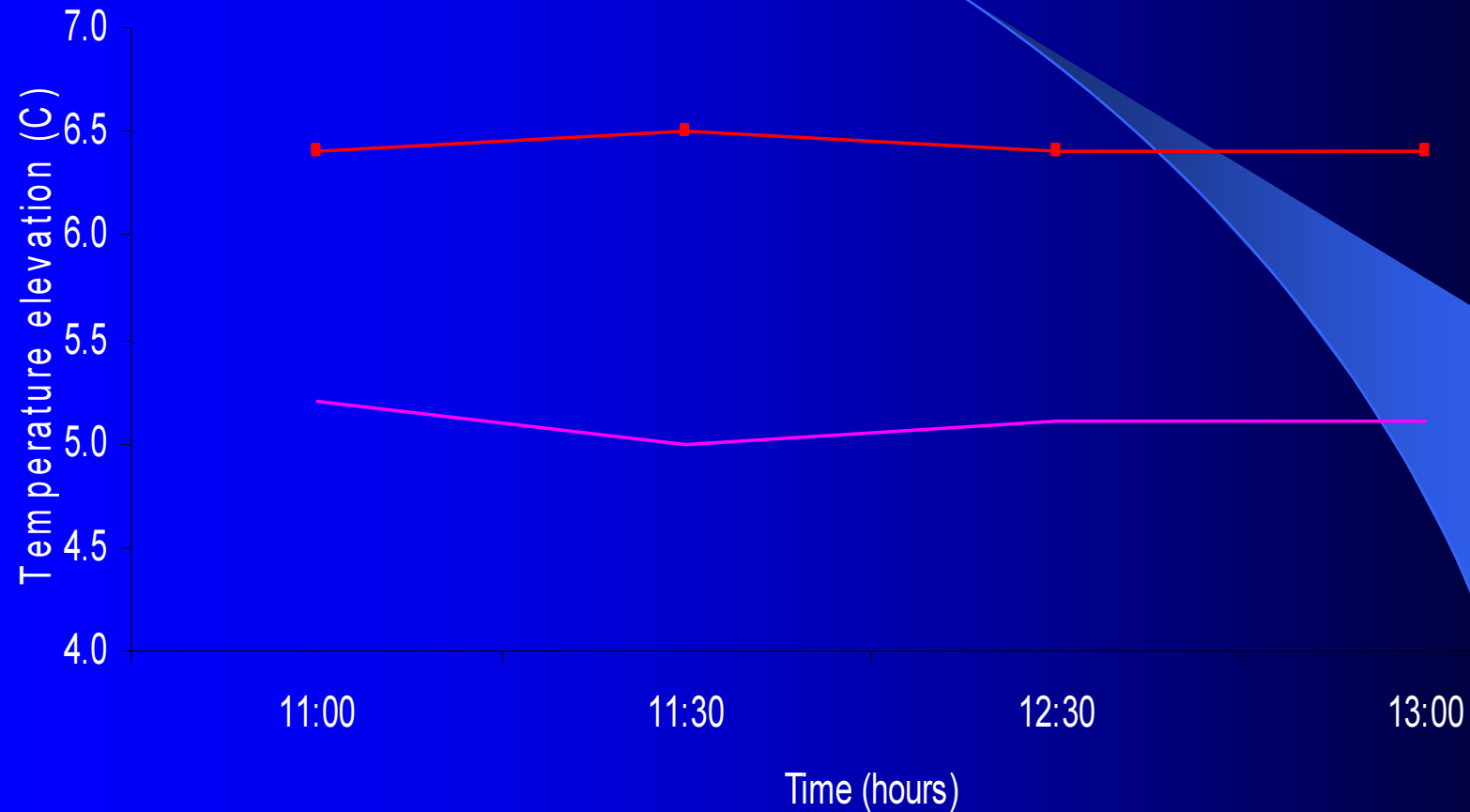


Testing of solar collector
At ISI marking laboratory
In Madurai Kamaraj University



Solar collectors : Test Results (Increase in temperature of working fluid)

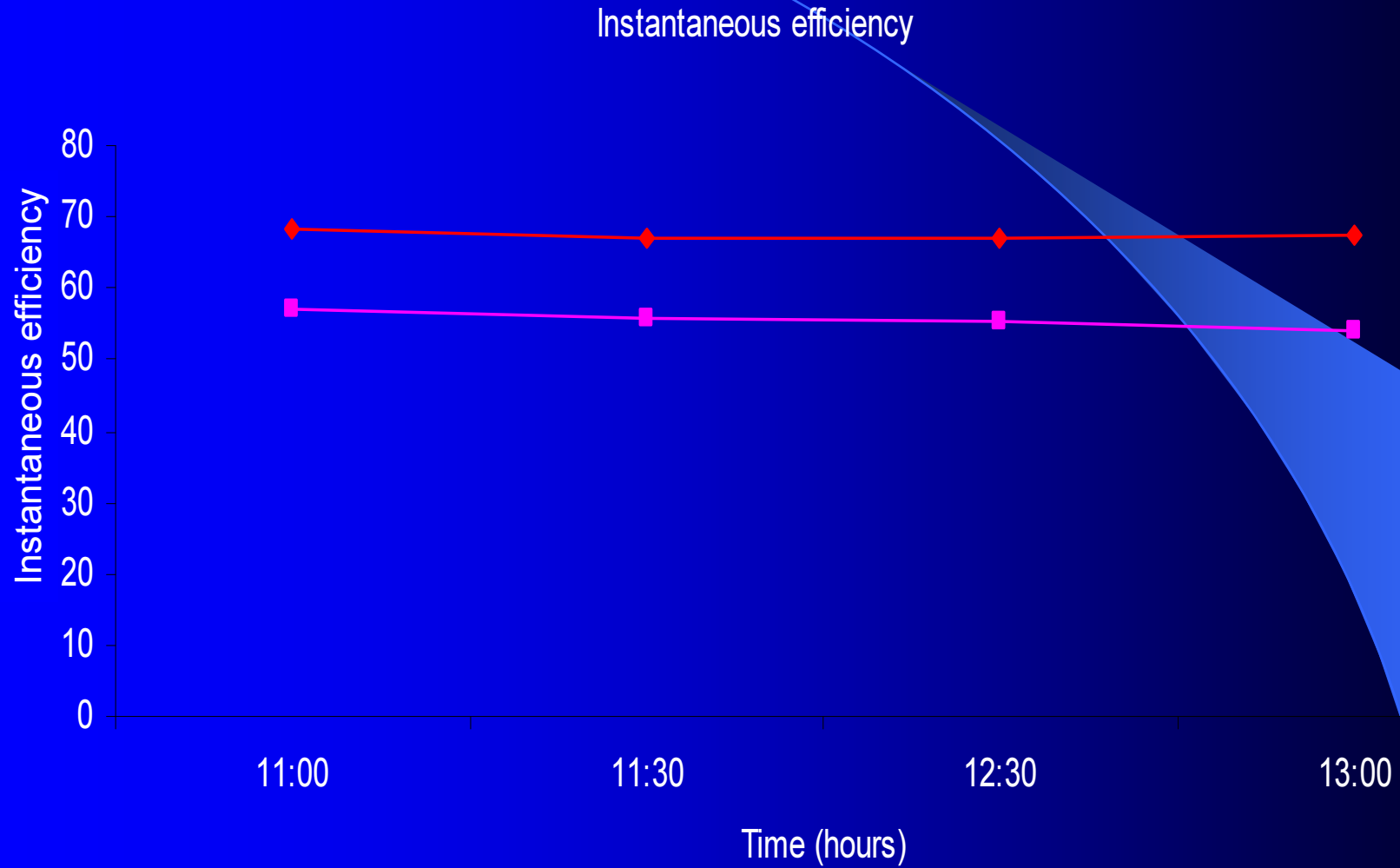
Increase in temperature of working fluid



— with normal level of solar radiation — with reduced level of solar radiation



Solar collectors : Test Results (Instantaneous efficiency)



◆ with normal level of solar radiation ■ with reduced level of solar radiation



Solar water heating systems used in Madurai city



125 lpd



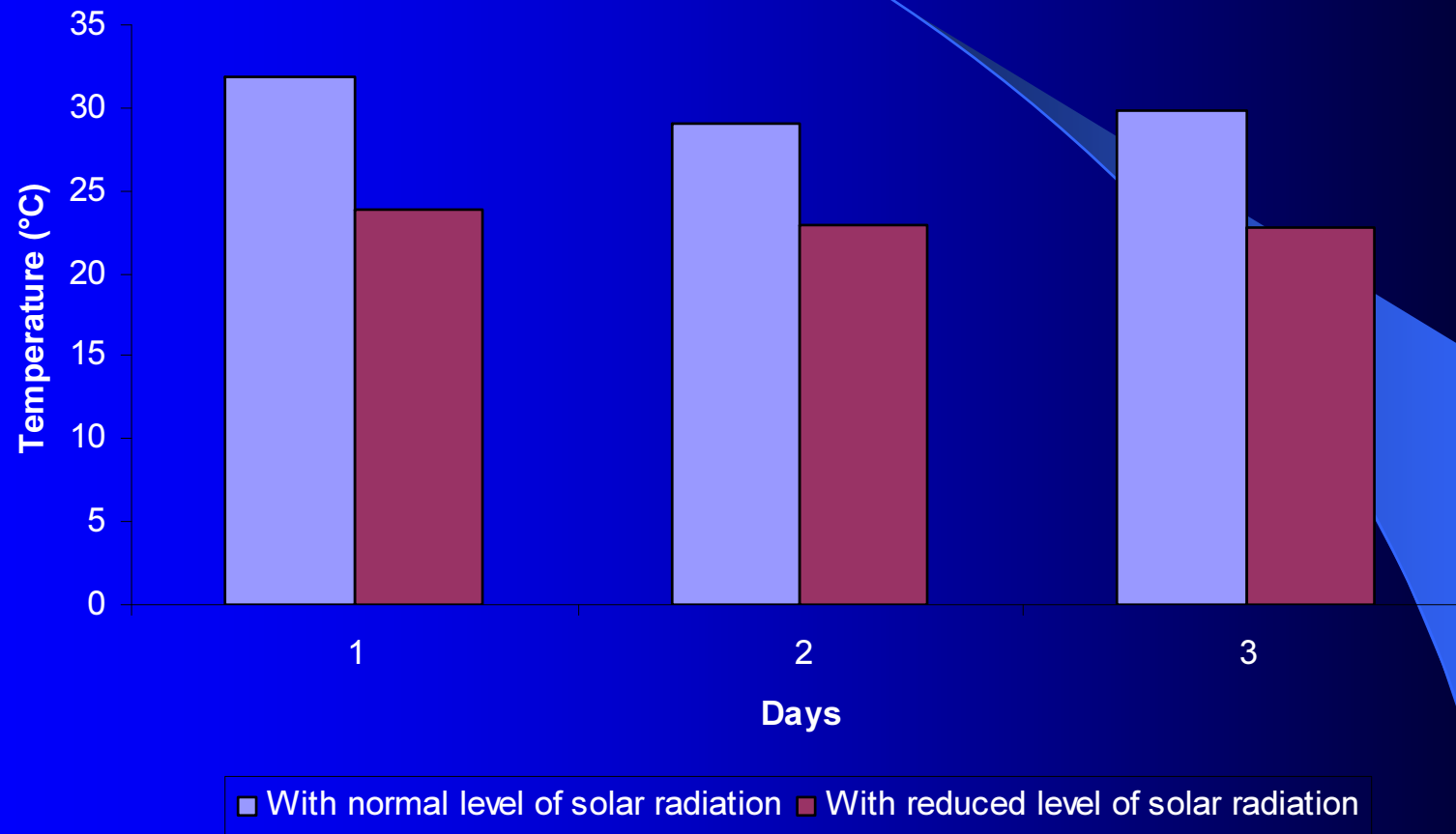
500 lpd



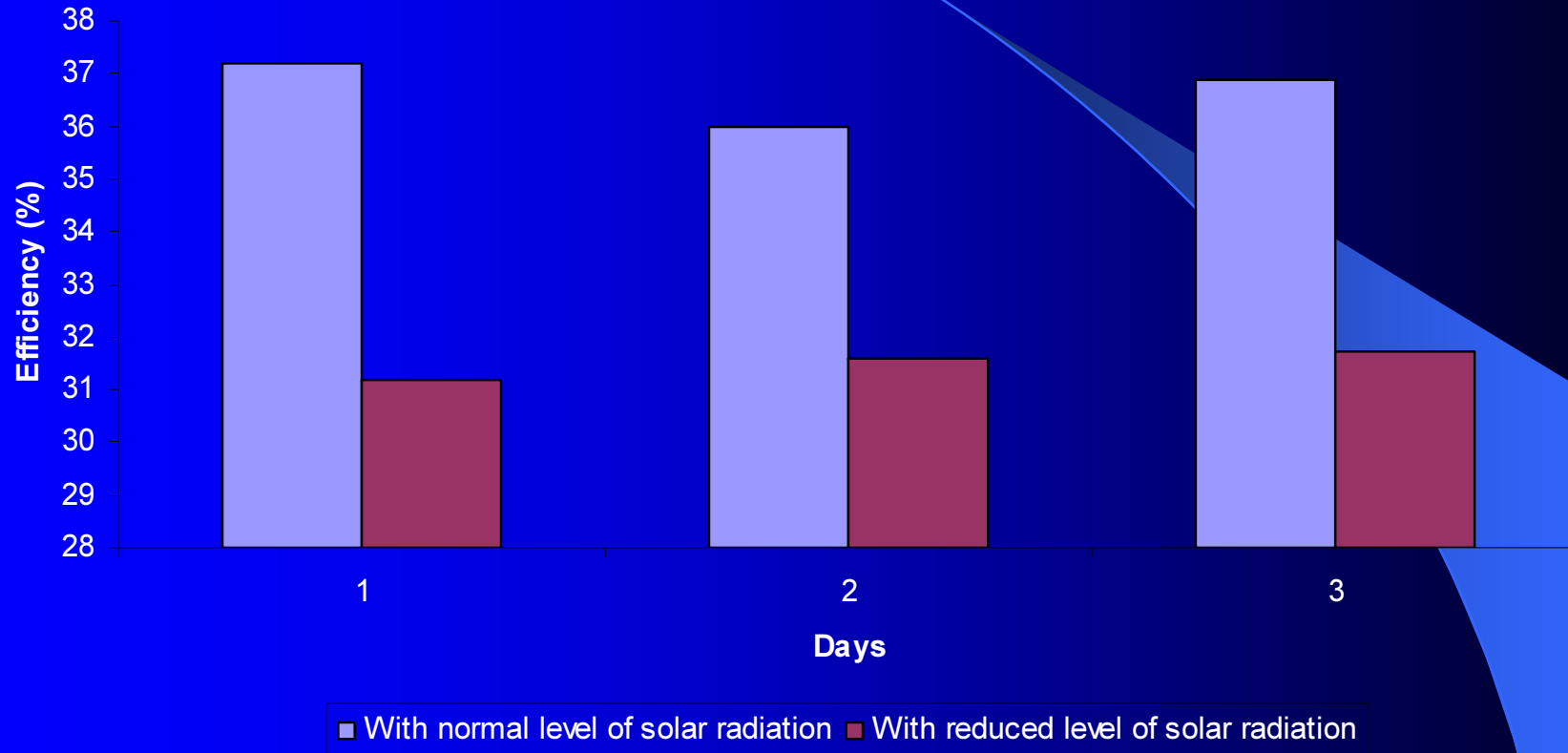
1000 lpd



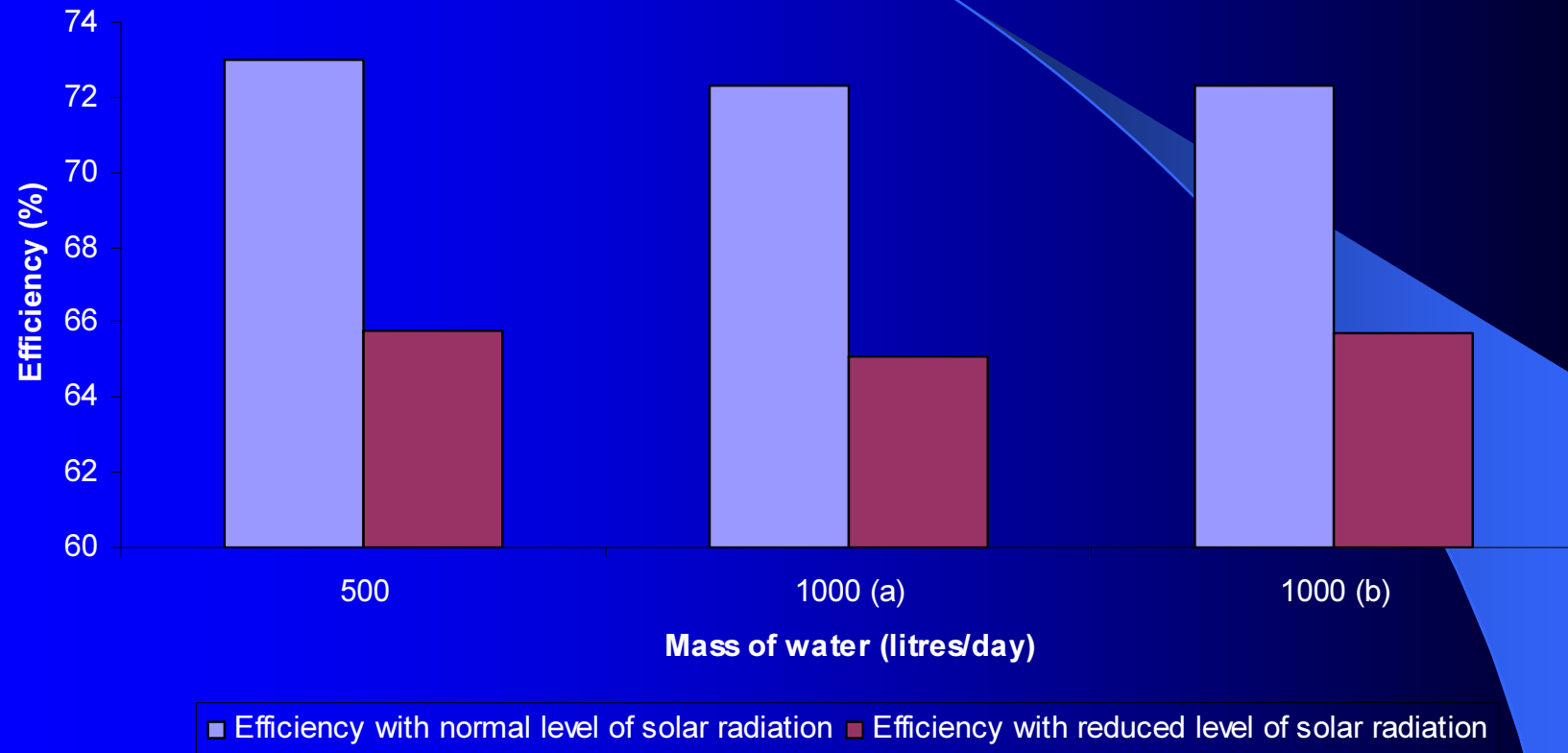
Solar water heating systems : Test Results (Increase in temperature of working fluid)



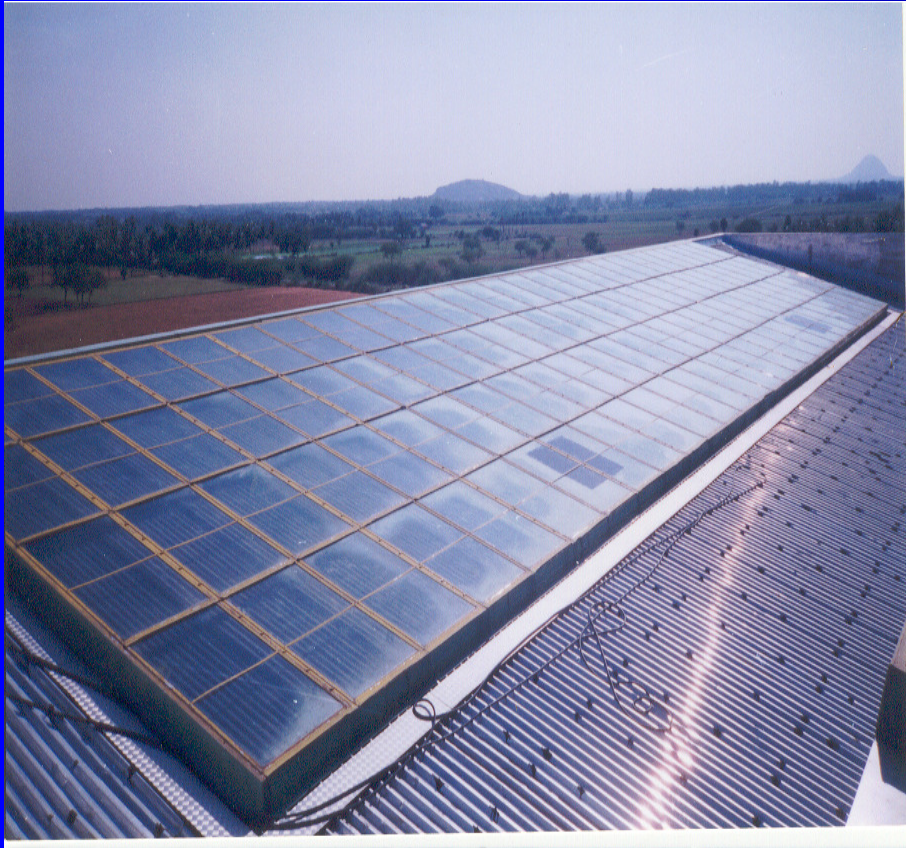
Solar water heating systems (100 lpd) : Test Results (Thermal efficiency)



Solar water heating systems (500 & 1000 lpd) : Test Results (Thermal efficiency)



Solar hot air systems used in Madurai city



Solar hot air systems used in Madurai city



Thermal performance of solar air heaters

	Normal condition	Reduced condition
Overflown-absorber solar air heater	43.4%	39.1%
Underflown absorber solar air heater	39.0%	35.6%

Solar parabolic concentrator : Test Results (Optical efficiency)



Solar parabolic concentrator

- ◆ Utilisation : Residential hostel of 120 University students
- ◆ Preparation : 120 meals / day 36 Kg of rice / Vegetables
- ◆ Energy saving : 60,000 MJ of fuel equivalent per year

Solar parabolic concentrator components

- Primary reflector (Area 7.14 m^2) / secondary reflector (Area 0.96 m^2)
/ clock mechanism)
- Temperature at the cooking pot : 480°C (at 955 Wm^{-2})

Optical efficiency

52.5% (with normal radiation)

41.9% (with reduced level of radiation)



Mitigation



Positive aspects prevailing in the city

- Lack of heavy industries
- Reliability of public transport system &
- Improvement in road network (over-bridges, traffic bays and subways)
- Existence of renewable gadgets in various energy-intensive sectors

Possible mitigation measures

- Increasing the efficiency of conventional fuel-based power plants
- Promotion of renewable energy
(Solar / Afforestation by energy crops / Biogas based lighting and cooking systems)
- Transportation
(Shift from road to rail transport, improvements in efficiency standards etc.,)

India and Nuclear Energy – A Snapshot

Number of reactors :

17 operating reactors / 7 under construction / 24 proposed by 2020

Contribution :

Only 3% (4120 Mw) of India's total energy output.

Projection :

Projections to 2030 call for nuclear energy share to rise from 3% to 26% to sustain the growth of demand for power

Expectation :

Coal-fired power production : From 67% to 47%

Oil and gas based power production : From 20% to 16%

Nuclear Energy in Kudankulam

Origin

Nuclear Power Corporation of India / Light water nuclear reactor

Location

240 Km from Madurai / Nearby Kanyakumari

Number of reactors :

8 number of 1000 MW reactors

Commissioning of the first unit of project

1 MW unit in December, 2010

Power supply :

Supply of electricity to Madurai region through TNEB



Adaptation



Adjustments in practices, processes, or structures to take into account climate change, to moderate potential damages, or to benefit from opportunities associated with climate change.”

- **Access of energy from nearby wind mills / hydro power stations**
Especially for common applications
(Street lighting / water pumping)
- **Conservation of Energy :**
Especially in industrial sectors
(Energy efficient lighting / waste minimisation etc)
- **Provision of renewable energy gadgets :**
Especially to domestic sectors
(Solar cookers / solar lanterns / Solar water heaters)
- **Provision of common renewable energy systems:**
Especially to domestic / commercial sectors
(Common solar desalination system / drying system)



- **Usage of renewable systems for community applications**

Especially to society

(Noon-meal preparation by using solar concentrators
Cooking and lighting applications by using by biomethanation
technologies with urban and solid wastes)

- **Provision of blueprints for solar passive architecture**

Especially to all energy-intensive sectors

- **Promotion of concentrators for process heat applications**

Especially to industrial sectors

- **Promotion of solar refrigeration and air conditioning technology**

Especially to all energy-intensive sectors

- **Promotion off-grid applications of solar energy**

(both SPV and Solar Thermal)

- **Reduction in vulnerability of resource base to climate change, variability and extreme events**

Embankment to protect from floods, cyclone centre, etc

- **Provision of common place powered by renewable technology**

Tamukkam

- **Provision of special grants / funds**

Especially for reestablishment of energy systems



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