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India Smart Grid Forum

India SMART UTILITY Week 2024

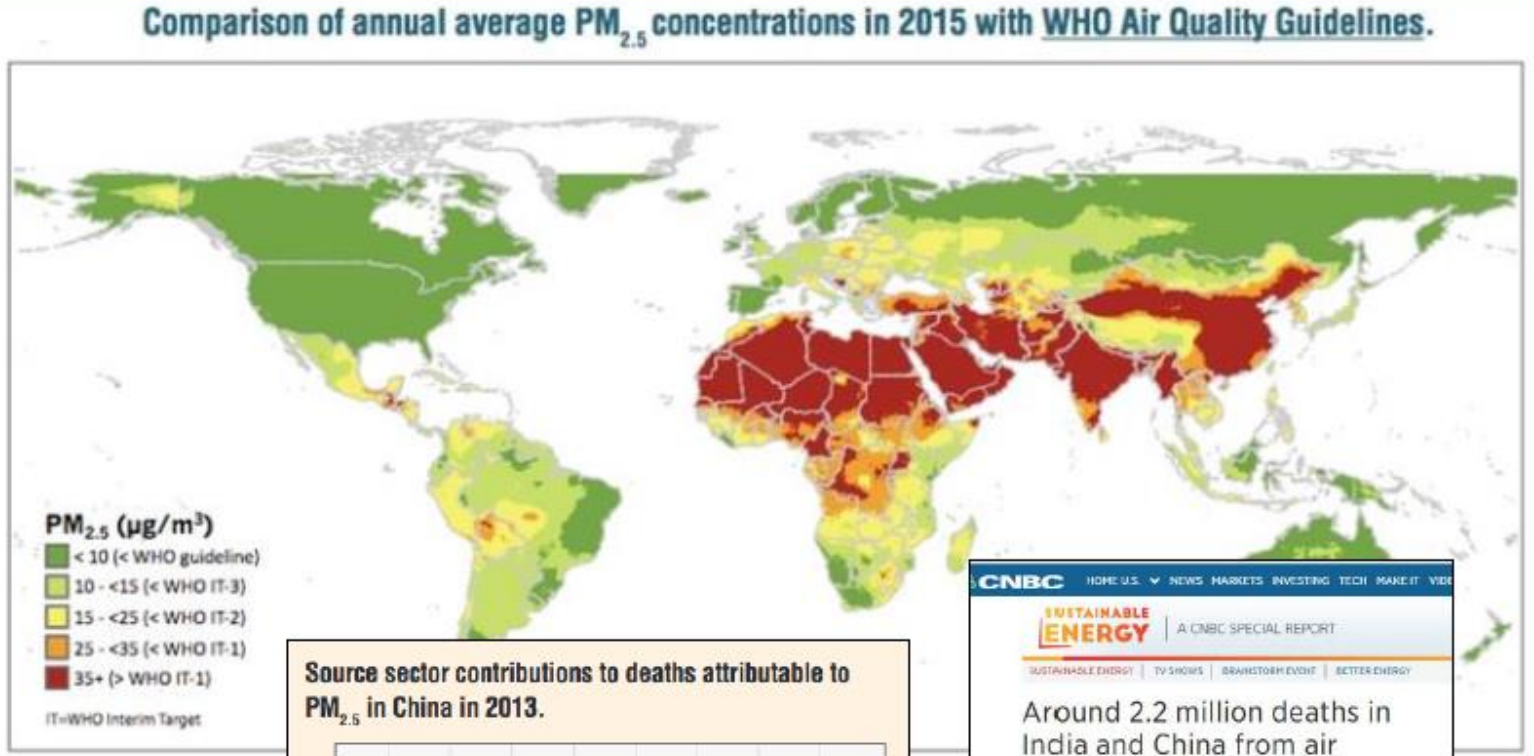
Supporting Ministries

Session : NUCLEAR RENAISSANCE AND THE ROLE OF SMR IN NET ZERO POWER SYSTEM

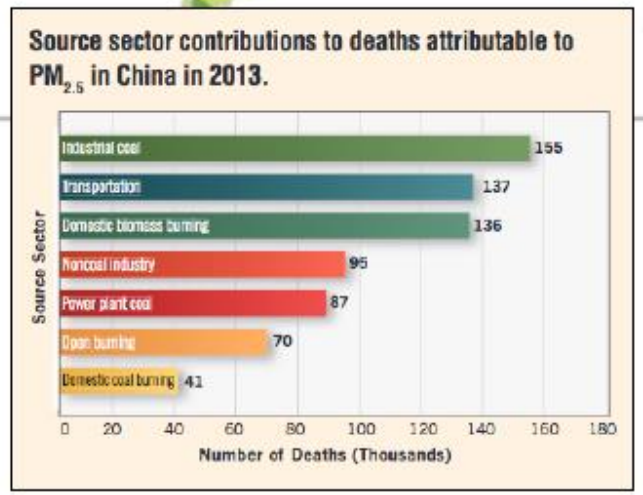
Chair's Opening Remarks

Ganapati Myneni, President & CEO, BSCE Systems, Inc., Yorktown, VA, USA

Driver for Nuclear in Asia: Deadly PM 2.5 Pollution



www.meo.life/state-of-global-air-2017/

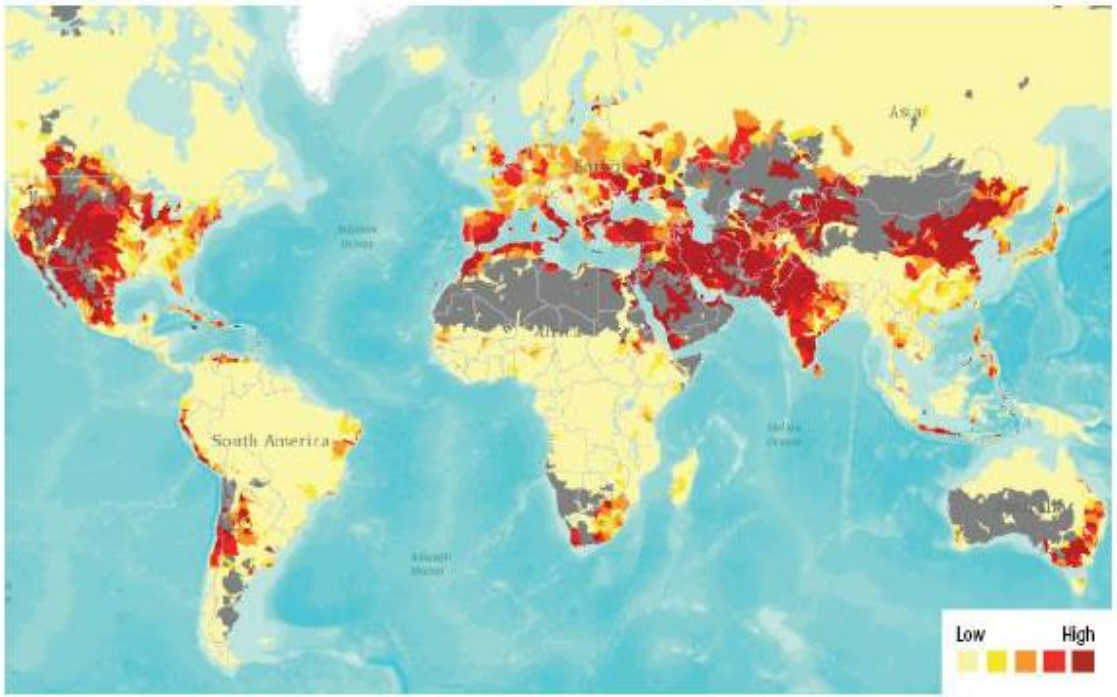


Andrew Paterson

WRI: Global Water Stress – and National Security

WRI: Water stress is not just a Developing World problem. Western USA.
WHO: Impact of urbanization -- "By 2025, half of the world's population will be living in water-stressed areas." Could Nuclear boost fresh water supply?

Projected Water Stress in 2030



Business as usual scenario
aqueduct.wri.org

AQUEDUCT WORLD RESOURCES INSTITUTE

Battle for Nile River Resources

200m people affected

6.5 GW Renaissance Dam [Ethiopia]

WRI (2017) www.wri.org/blog/2017/02/what-does-water-have-do-national-security

Andrew Paterson

Global SMRs in "Discussion" now > $70 Billion in total value, 2023

China or Russia	Stage of Development
Fuel load / Ops	5
Under Constr	4
Financing signed	3
Siting selected	2
JV Formed	1

Standard LWR
Advanced unit

China & Russia lead deployment of SMRs ... Industrial and Arctic applications
What will USA and Europe do to recover leadership?

		Projects 22		Operating by Average 2029	MWs Average 190	[Reactors] Units 60	Total MWs 9,168	$Billions Total Cost $85.60 B	$Millions Cost per MW $9.3 M
Locale	Expected SMR Project	SMR Site	Reactor	Operating Date	Size (MWs)	Number (Reactors)	Total MWs	Project Cost ($Billion)	Cost per MW ($Mil)
~~USA, Utah~~	~~UAMPS~~	~~Idaho~~	~~NuScale LWR~~	2030	77	6	462	$8.00 B	$17.3 M
USA, several	NUCOR EAFs	Several: KY, WV	NuScale LWR	2030	77	12	924	$12.00 B	$13.0 M
CAN, Ontario	OPG	Darlington, ON	GE LWR	2028	300	1	300	$1.80 B	$6.0 M
UK Site	RR SMR	Wales, UK TBD	Rolls Royce	2030	470	3	1410	$9.00 B	$6.4 M
UK Site	RR SMR	Moreside, UK	Rolls Royce	2032	470	2	940	$6.00 B	$6.4 M
CAN, NB	NB SMR	Pt. LePreau, NB	Moltex AMR	2029	300	1	300	$2.50 B	$8.3 M
CAN, Ontario	CNL	Chalk River, ON	USNC Micro	2027	5	1	5	$0.40 B	$80.0 M
USA, Alaska	US Air Force SMR	Elelson base, AK	AMR Micro	2027	5	1	5	$0.50 B	$100.0 M
USA DOE ARDP	TerraPower	Kemmerer, WY	Natrium AMR	2032	345	1	345	$3.50 B	$10.1 M
USA DOE ARDP	DOW Chem	Freemont, TX	X-e 100	2032	80	4	320	$4.20 B	$13.1 M
USA DOE ARDP	X-energy	Hanford, WA	X-e 100	2032	80	2	160	$2.40 B	$15.0 M
Poland	PKN Orlen	Multiple sites	GE-BWRX	2030	300	4	1200	$8.00 B	$6.7 M
Poland	SYNTHOS	Oświęcim, PL	LWR SMR	2030	300	1	300	$2.50 B	$8.3 M
Bulgaria	Industrial AMR	Maritsa Iztok, BG	AMR	2028	80	6	480	$7.20 B	$15.0 M
Slovenia	Krško-2	Krško site, SLO	LWR SMR	2030	300	2	600	$4.00 B	$6.7 M
Romania	Cernavoda SMR	Cernavoda, ROM	NuScale LWR	2028	77	6	462	$6.00 B	$13.0 M
CH, Shanghai	China NNC AMR	Shandong AMR	HTR-PM	2024	210	1	210	$1.40 B	$6.7 M
RU, Siberia	Seversk Chemical + Rosatom MOX	Seversk, RU	TVEL BREST Lead-cooled	2027	300	1	300	$2.00 B	$6.7 M
RU, Arctic Circle	Arctic Port	Pevek, RU	2 x KLT-40C	2020	35	2	70	$0.50 B	$7.1 M
CH, Hainan	CNNC	Changjiang	ACP100 PWR	2026	125	1	125	$1.50 B	$12.0 M
CH, Floating	CNNC	Floating SMR	ACP100 PWR	2028	125	1	125	$1.20 B	$9.6 M

SMR Projects in the Global "Arena" top $70 billion in estimated project value (20+ projects)

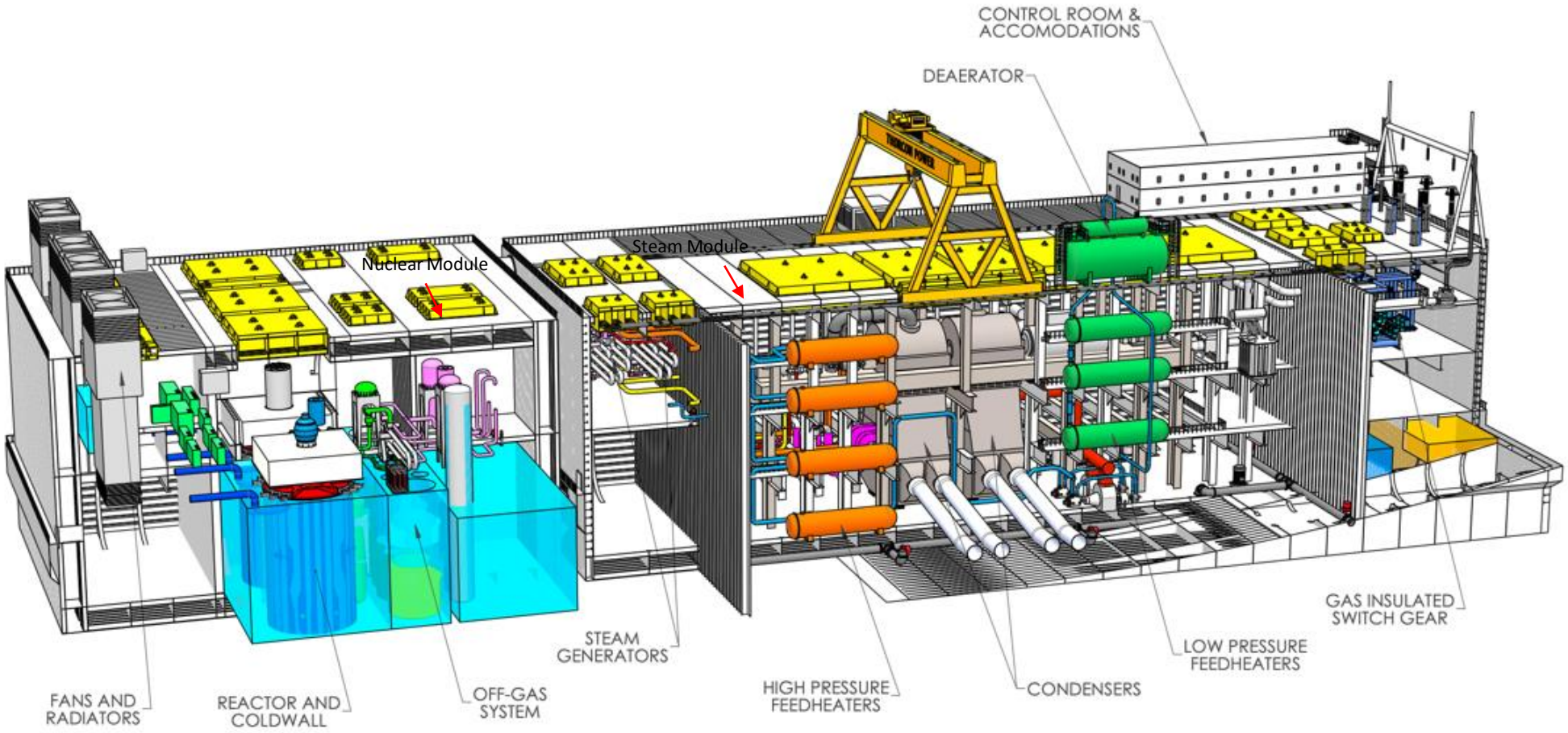
At various stages of development, SMR projects announced by vendors, engineering partners and governments (for siting or investment) have reached over $70 billion in projected capital investment – more than 20 projects including at least 40 reactors for a combined total topping 8-9 GWs. Most of that capital investment lies in the future, as projects are still at various stages of development: from 1) Announced plan and JV by a Government; 2) Selected site with permits in view; 3) Financing signed – the biggest hurdle it seems; 4) Under construction; 5) Fuel loading and operation in a few cases. Each of these five stages represent a significant milestone with multiple stakeholders and a clear decision point.
Cost estimates are still moving around due to the earlier stage of projects; some estimates are high and some are low, so the combined list should be near an expected value.

The table notes the Stage of Development of a project and highlights China & Russia versus allied actors. Also, whether the reactor design is a conventional LWR (either a BWR or PWR, Gen III) vs a more advanced "AMR" reactor with designer shown. Micro-reactors (sub-20 MWs) are for specialty applications and remote facilities (e.g., Arctic ports and stations).

EBI

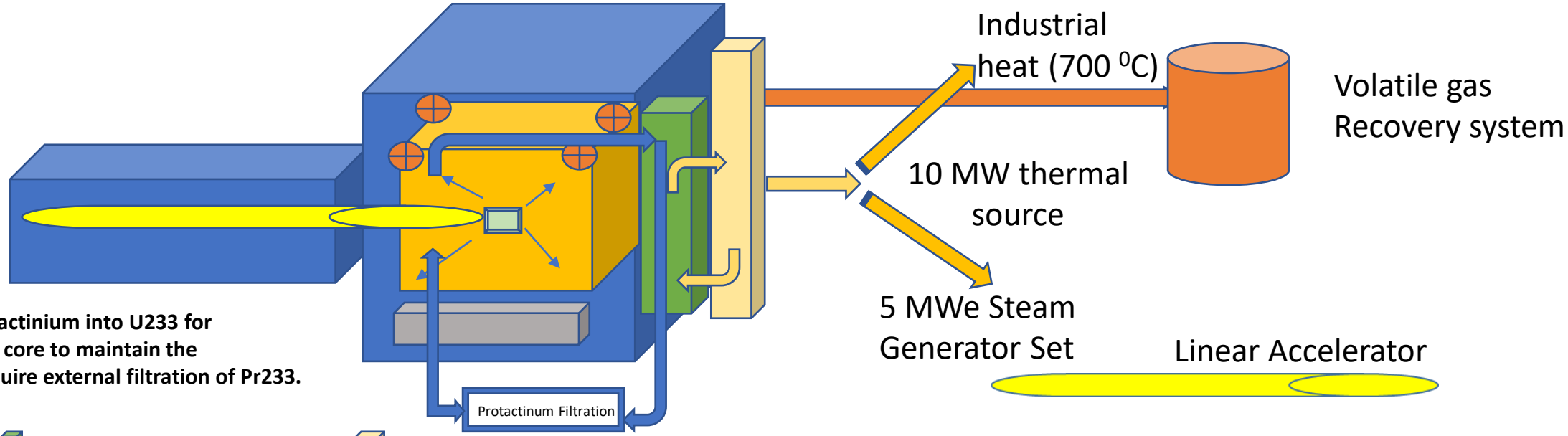
500 MW ThorCon Molten Salt Reactor Power Plant

Demonstration Plant to Be Tested for Licensing in Indonesia



Built in shipyard, towed to site, ballasted down onto seabed.
Nuclear Module is replaced every 8 years

Subcritical Nuclear Reactor – 10 MWt/5 Mwe
Low Cost, Incremental Power Route to a Zero Carbon Future



Filtration of Protactinium into U233 for return to reactor core to maintain the reaction may require external filtration of Pr233.

Internal Salt Heat Exchange *(Hastelloy)*

External Salt Heat Exchange (Stainless Steel)

Electron from LINAC

Beryllium-U233 target

Neutrons

Overflow salt storage tank

Salt pump

Exhaust system

Graphite/Hastelloy Reactor Circulating U233/Thorium Beryllium Salt

Reinforced concrete Enclosures for LINAC and molten salt reactor

ANSI/ANS-20.2-2023

Nuclear Safety Design Criteria and Functional Performance Requirements for Liquid-Fuel Molten Salt Reactor Nuclear Power Plants

An American National Standard

Published by the
American Nuclear Society

Underwriter Certification of Nuclear Power

First Edition

Jack Devanney

Sisyphus Beach

Tavernier, Florida

2024

"About the Conference"

Hydrogen has an important role to play in the decarbonization of industry and transport sector.

While hydrogen produced from renewable electricity is an important part of the low carbon future, nuclear hydrogen is also equally clean and has considerably higher potential to contribute to future energy scenario for deep decarbonization.

Various hydrogen production technologies which can be coupled with nuclear energy include electrolysis, high temperature steam electrolysis and thermochemical processes. Nuclear power here is produced through a variety of nuclear reactors, which includes small modular reactors, high temperature reactors and innovative accelerator based nuclear technologies.

INHC is aimed at bringing together all stake holders on one platform to discuss the opportunity and challenges in nuclear hydrogen and arrive at a road map for future hydrogen economy in India.

Register https://events.ntpc.co.in/inhc

INTERNATIONAL NUCLEAR HYDROGEN CONFERENCE (INHC-2024)

August 19-20th, 2024

Theme: Integration of Nuclear & Hydrogen for Energy Transition

Venue: Power Management Institute, NTPC Limited, Film City, Sector-16A, Noida (Uttar Pradesh), India-201301

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