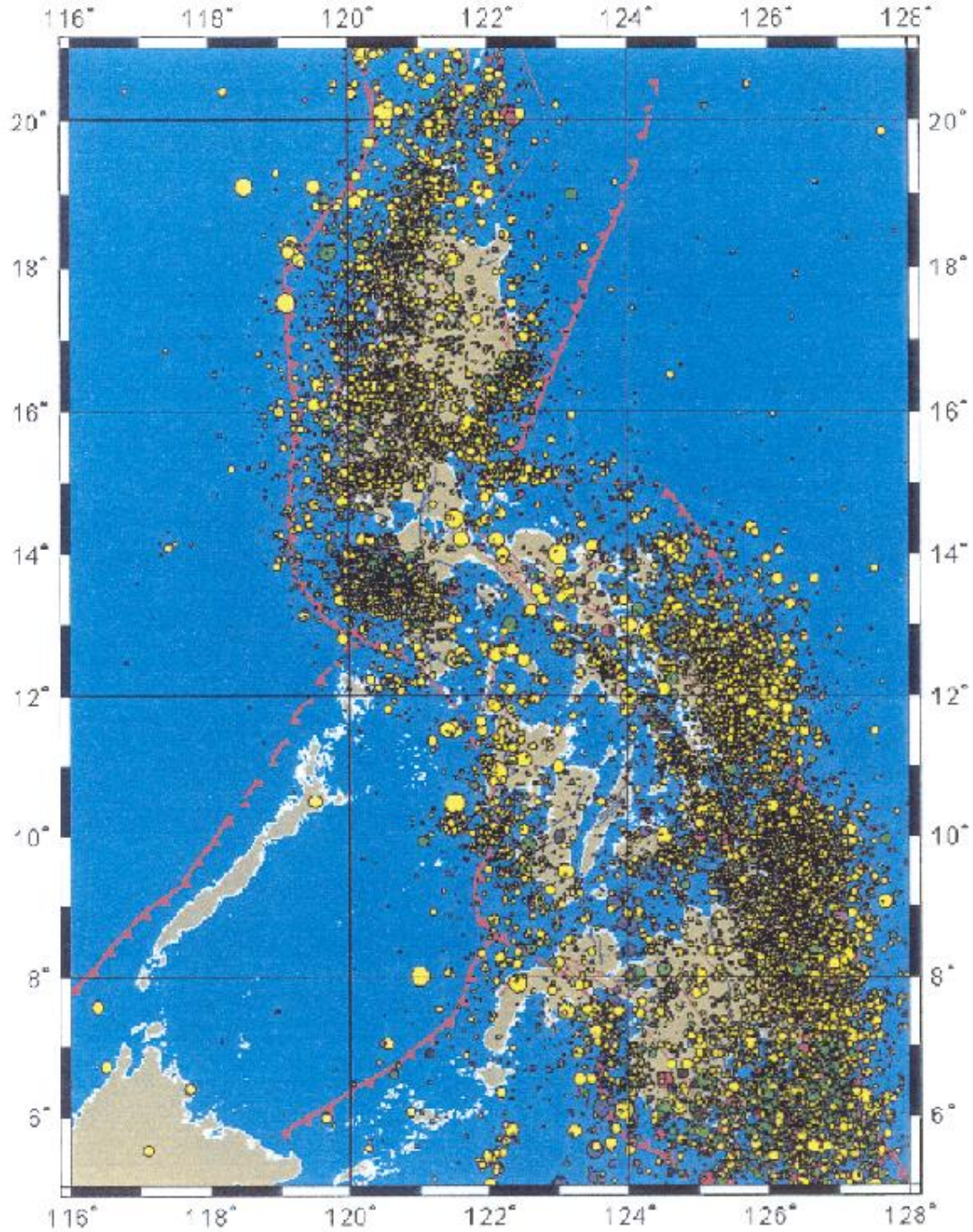
Nuclear Power: in the Philippines?

Dr. Carlo Arcilla

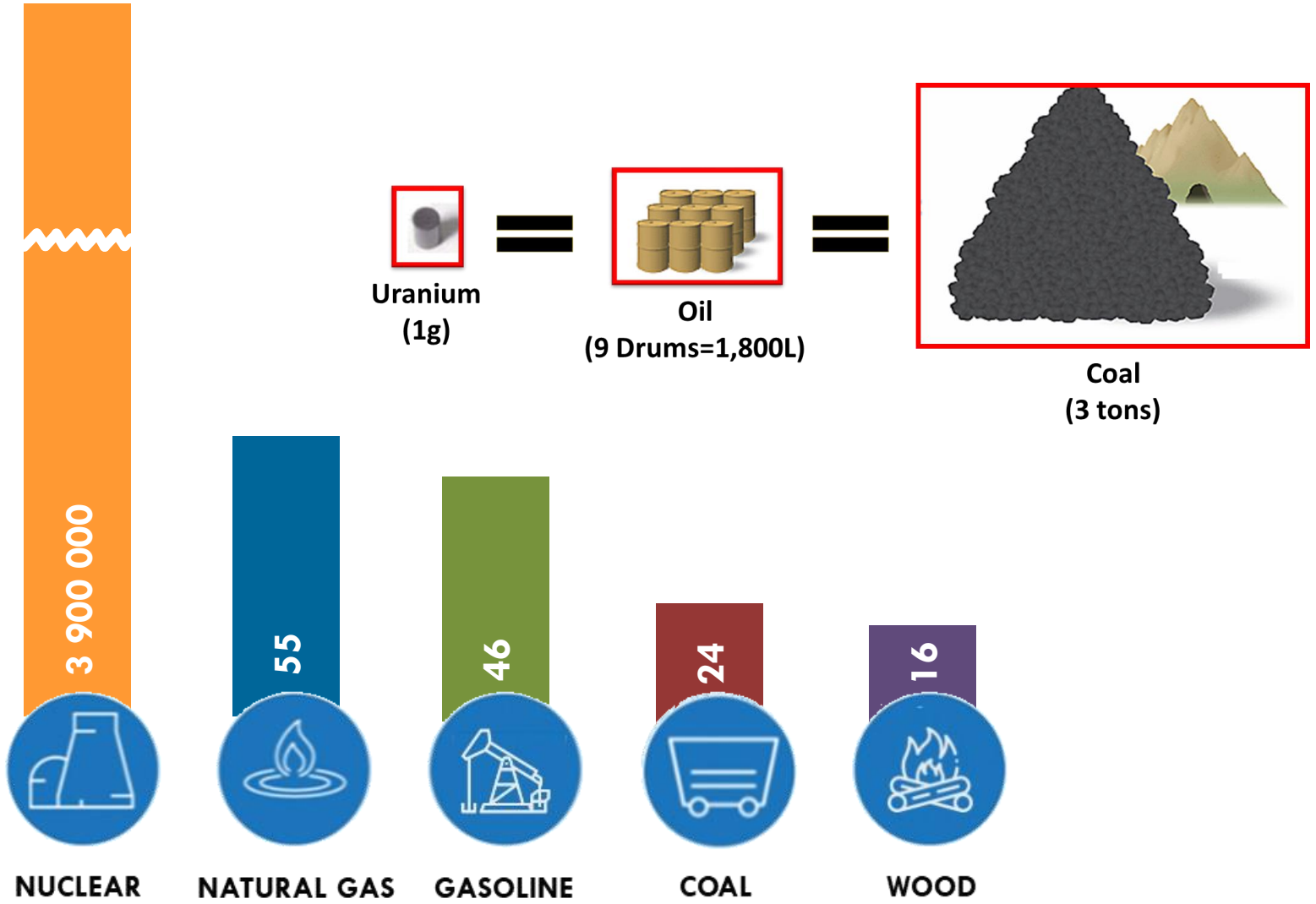
Director, PNRI


116°
118°
120°
122°
124°
126°
128°
20°
18°
16°
14°
12°
10°
8°
6°

Disasters in Philippines

- Typhoons (20 a year)
- Volcanoes
- Tsunami
- Earthquakes
- Floods

Energy density (MJ/kg) by energy source



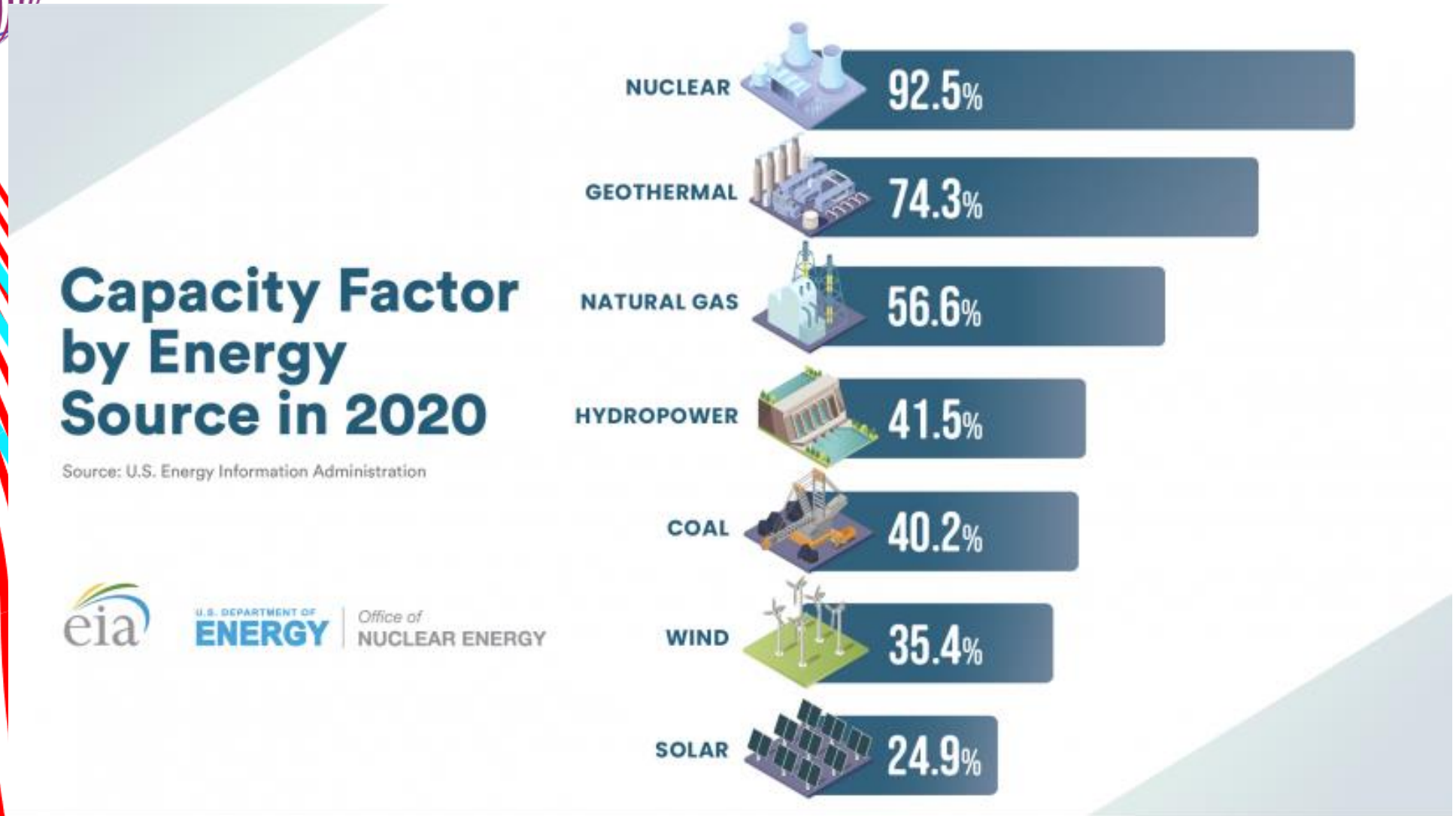
Nuclear Fuel:
Small volumes, high energy contents

- 1 pellet produces the energy of 1.5 tonnes of coal
- Each pellet produces 5000 kWh

IAEA

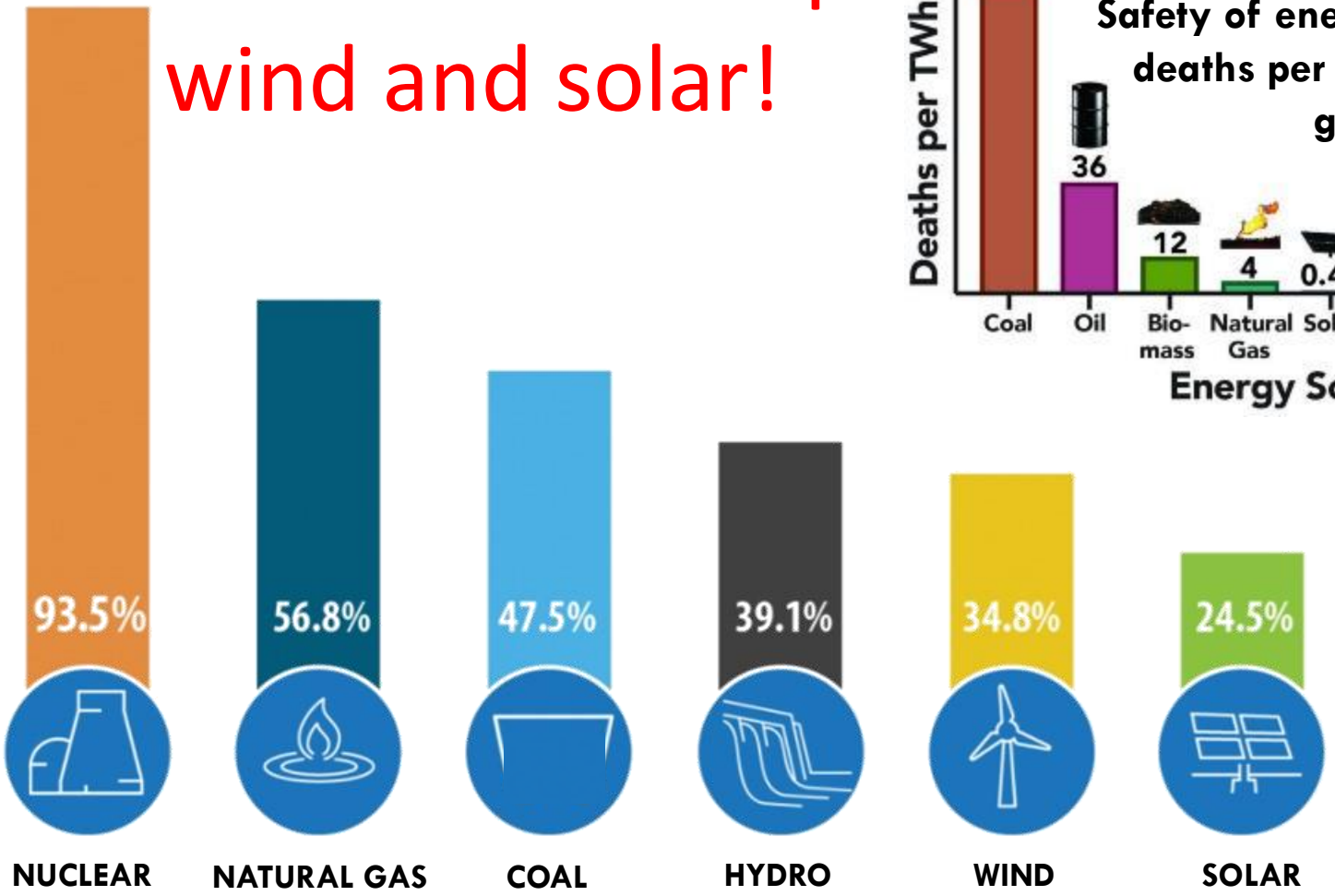
BNFL

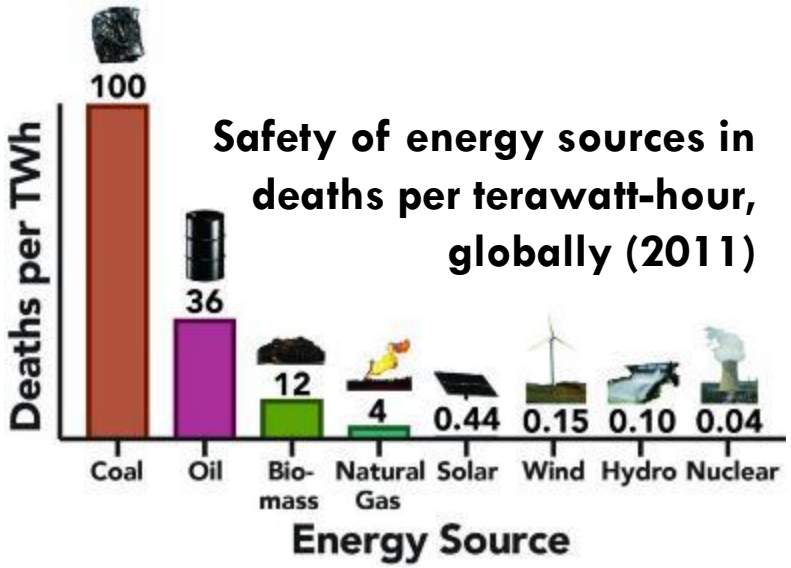
CAPACITY FACTOR
BY ENERGY SOURCE



Capacity factor and safety by energy source

Nuclear can backup wind and solar!





Source: U.S. Energy Information Administration, 2019

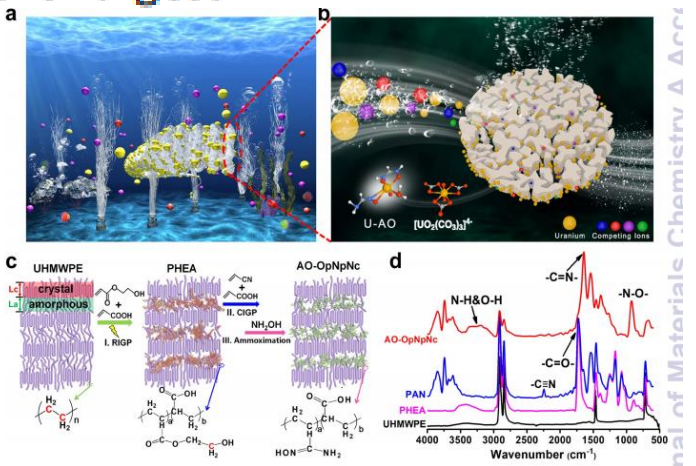
Nuclear is now renewable!

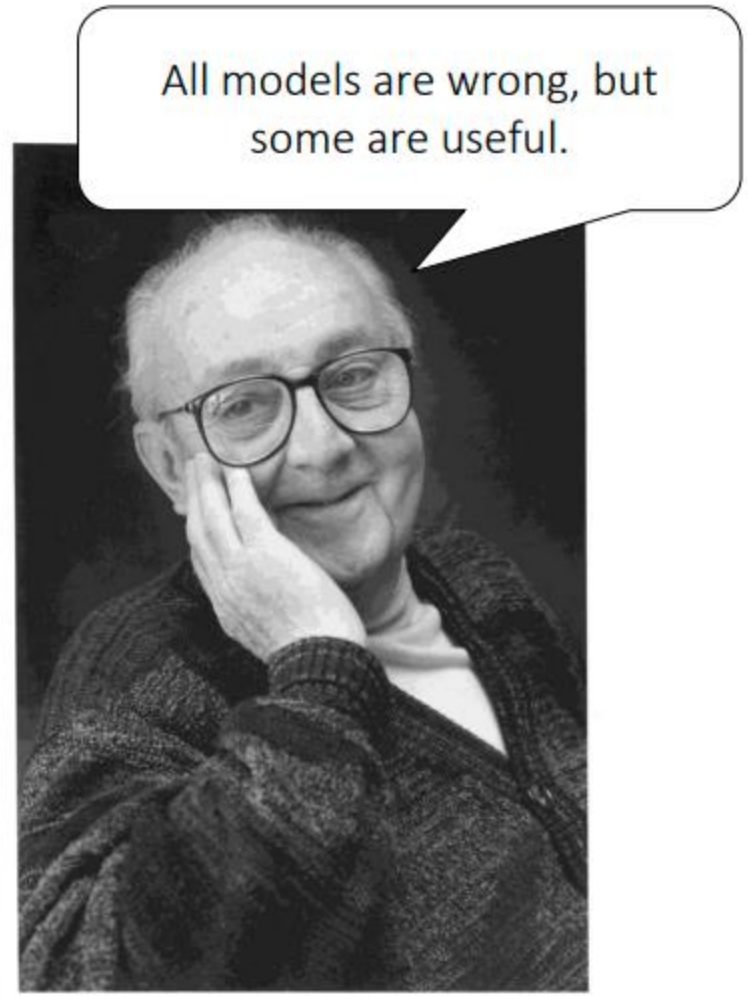
Ultrahigh and Economical Uranium Extraction from Seawater Via Interconnected Open-Pore Architecture Poly(amidoxime) Fiber

Article *in* Journal of Materials Chemistry A · September 2020

DOI: 10.1039/D0TA07180C

EXAFS and DFT computational studies. The high uranium adsorption capacity of 17.57 mg-U/g-adsorbent in natural seawater with a service life of 30 adsorption-desorption cycles resulted in a UPC of $80.70–86.25 per kg of uranium, which is a significant milestone in the process of UES. The exceptional durability, high efficiency, and economic AO-OpNpNc fiber is a promising adsorbent to eventually provide commercially attractive nuclear fuel derived from the oceans—the largest source of uranium on earth.





George Edward Pelham Box, British statistician.

Combination of gas, nuclear power and renewables provides delivery at acceptable costs

Gas and nuclear power in combination with renewables provides stable delivery at acceptable costs

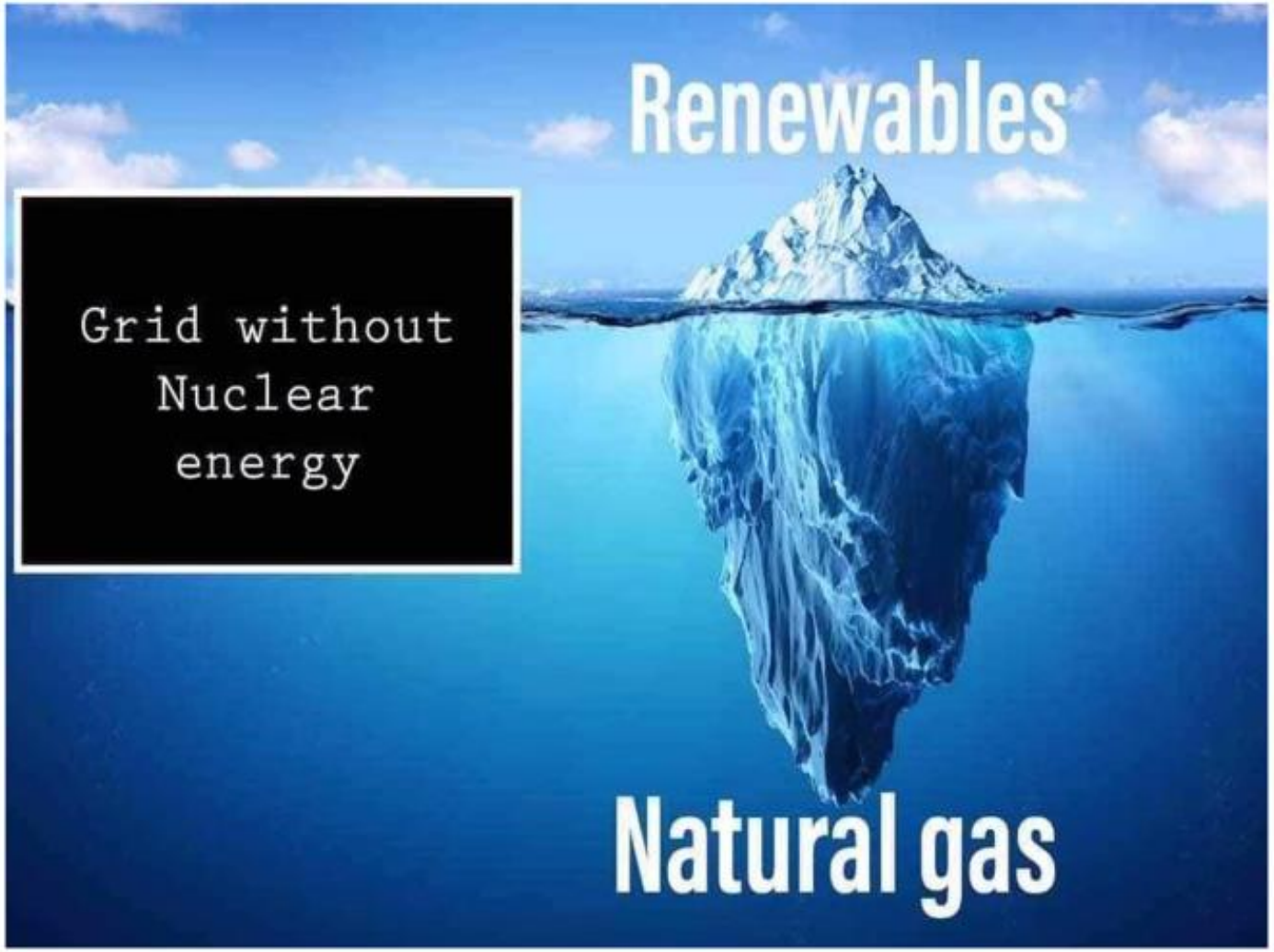
All energy sources have their advantages and disadvantages in terms of cost, stability and waste. While nuclear power has unprecedented stability, the energy source has clear challenges in terms of radioactive waste. The fossil fuels have large emissions of CO2 and harmful gases. Coal and biomass power struggle with large amounts of ash waste associated with the combustion process. Gas-fired power plants are both stable and cheap but must be combined with expensive carbon storage to limit emissions. Wind and solar power have very low greenhouse gas emissions, but produces significant waste, while providing unstable power and high costs if batteries are to be used for storage. It is therefore all about establishing a future power mix that maximizes the benefits and minimizes the disadvantages. This requires fact-based detail knowledge of how each energy source affects health, climate, the environment and the economy.

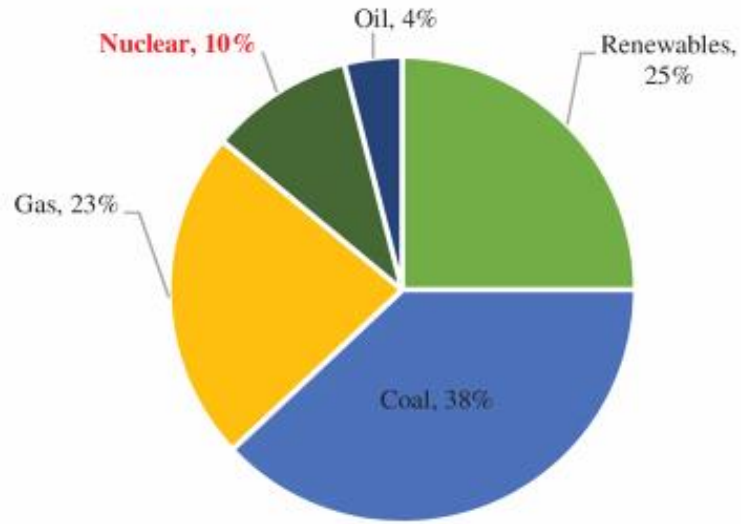
Not about either, or – balanced mix is needed

It is not about either or

It is not possible to deliver energy without negative consequences. It is all about finding a balance that is acceptable and providing the lowest possible total footprint. No single energy source can solve the climate challenge alone, and a power mix consisting only of renewables will, in addition to having practical and economic challenges, bring unnecessarily large negative consequences for nature and the environment. A constructive climate debate therefore requires an understanding of each energy source's impact on climate, environment, health and economy. Hopefully, the work I have done, with good help from geophysics student Wouter Bell Gravendeel, and documented in four different articles, can contribute in the right direction.

Pizza Party

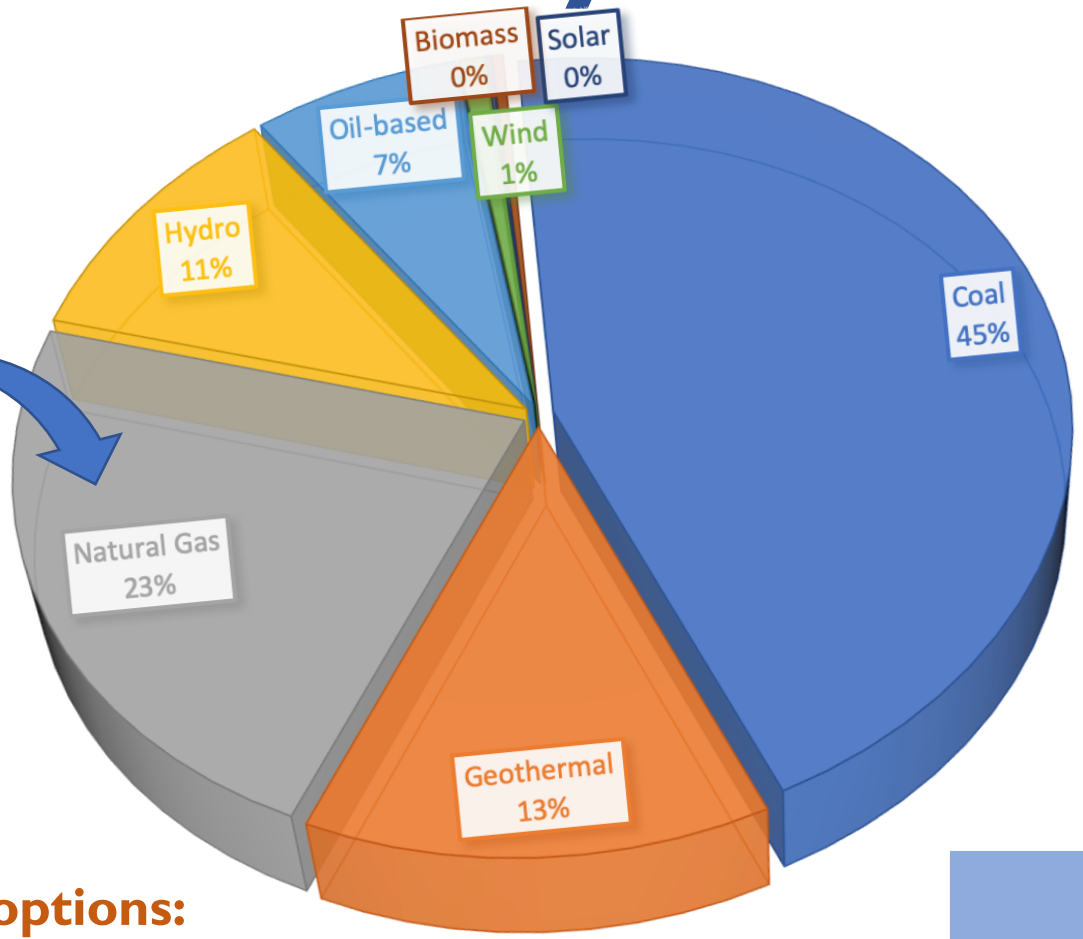




4천만톤 수입, 1800만톤 발전(1/2 민간발전사), 1900만톤 도시가스

PHL Electricity Mix

The current energy mix is composed of coal (47%), natural gas (22%), renewable energy (hydro, geothermal, wind, solar) (24%), and oil-based (6.2%) with current energy capacity at 23GW



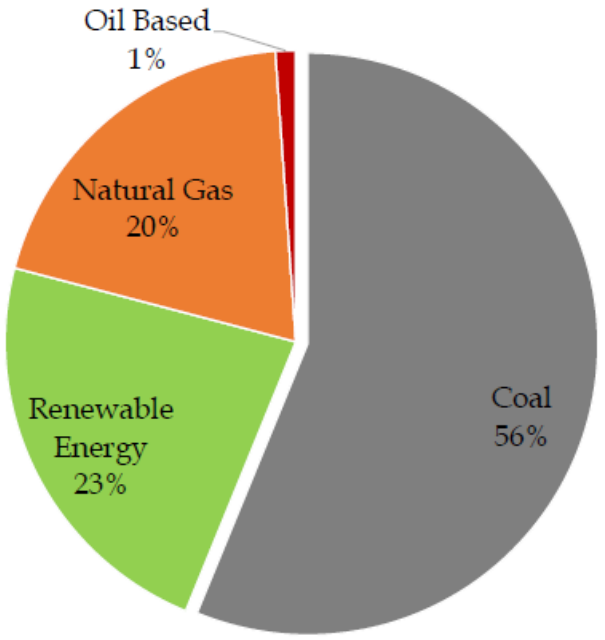
Malampaya gas running out in 5 years

Best replacement options: Liquefied Natural Gas (LNG) along with Nuclear Energy

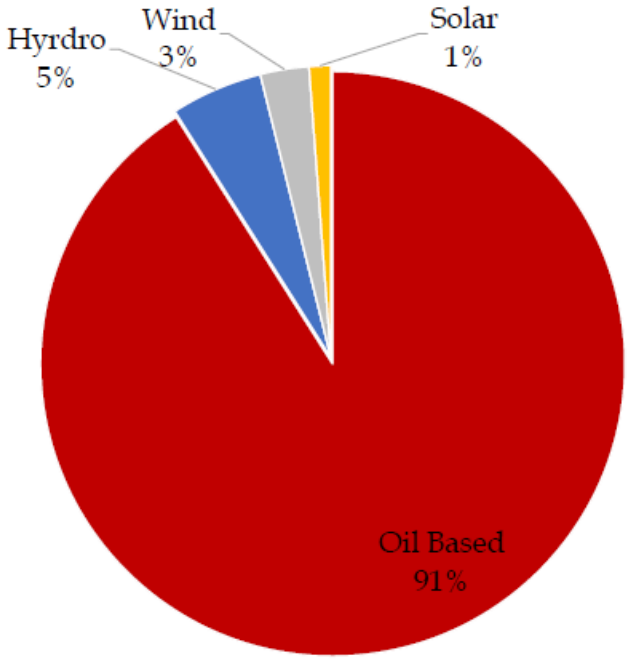
THE REALITY CHECK

Energy Mix

2022 Gross Energy Generation Mix - Main Grid (1ST Quarter)



2020 Energy Generation Mix for Off-Grid



LNG prices from $10M to $281M in one year- 2020-2021!

(Malampaya supplies 40% of Luzon power)

Why Nuclear ?

A median Filipino family pays more than 10% of its monthly income for electricity!

High electricity costs **could be** reason why 79% of PHL population supports nuclear power (DOE Survey, May 2019)

Nuclear is competitive with gas and coal but small volume favors energy security

SAFETY, SAFETY, SAFETY

If nuclear is unsafe why does USA have nearly 100 NPP, suppying 20% of its electricity, operating close to 60 years?

Nuclear Power by the Numbers (Asia)

130

Operable nuclear power reactors

35

Under construction

70-80

Planned

UAE have finished and **Bangladesh** are nearly finished constructing their first nuclear power plants.

Source: www.nuclear.gov/nuclear

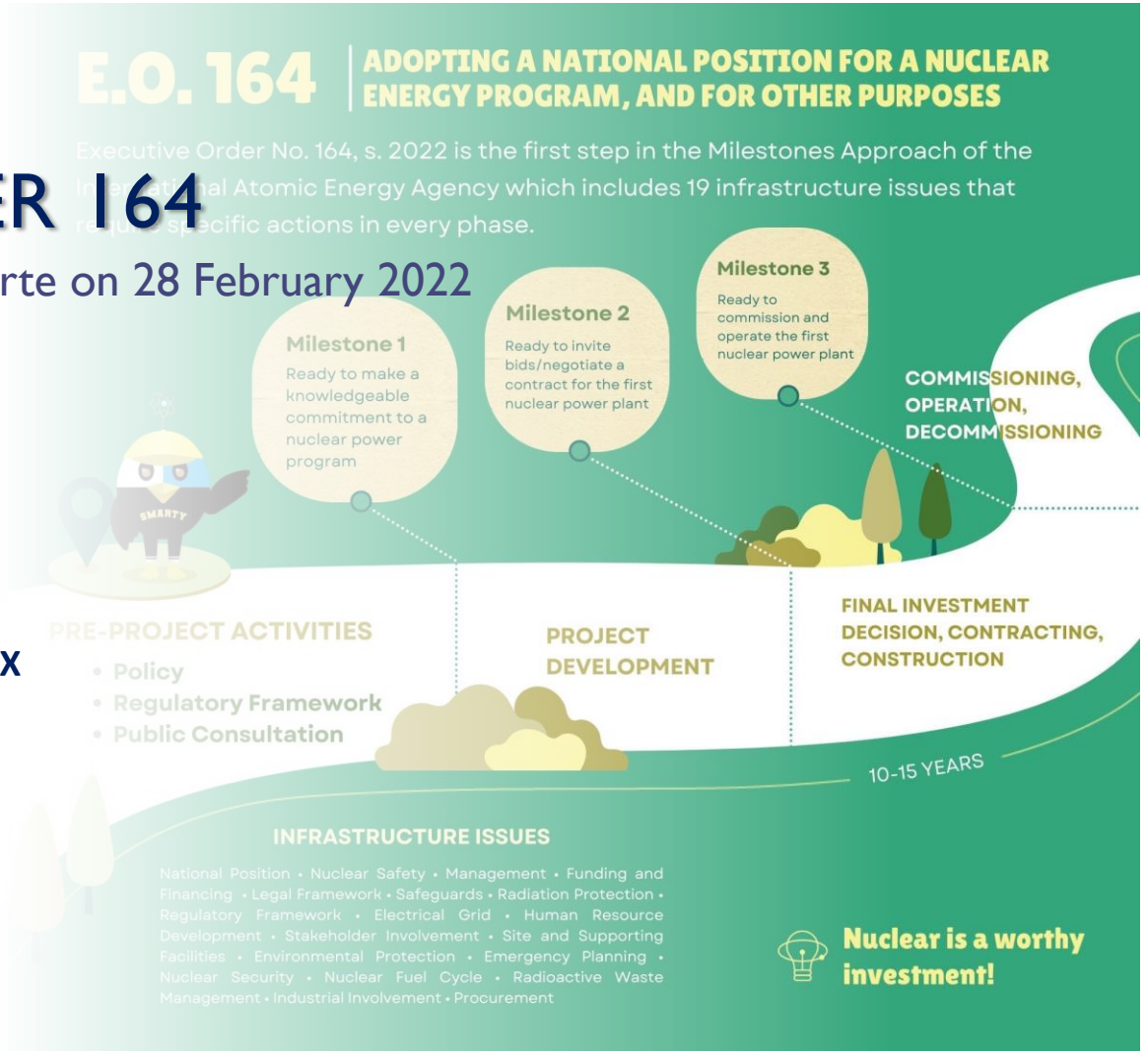
EXECUTIVE ORDER 164

Signed by President Rodrigo Duterte on 28 February 2022

NUCLEAR ENERGY PROGRAM

STARTS WITH THE INCLUSION OF NUCLEAR POWER IN THE ENERGY MIX

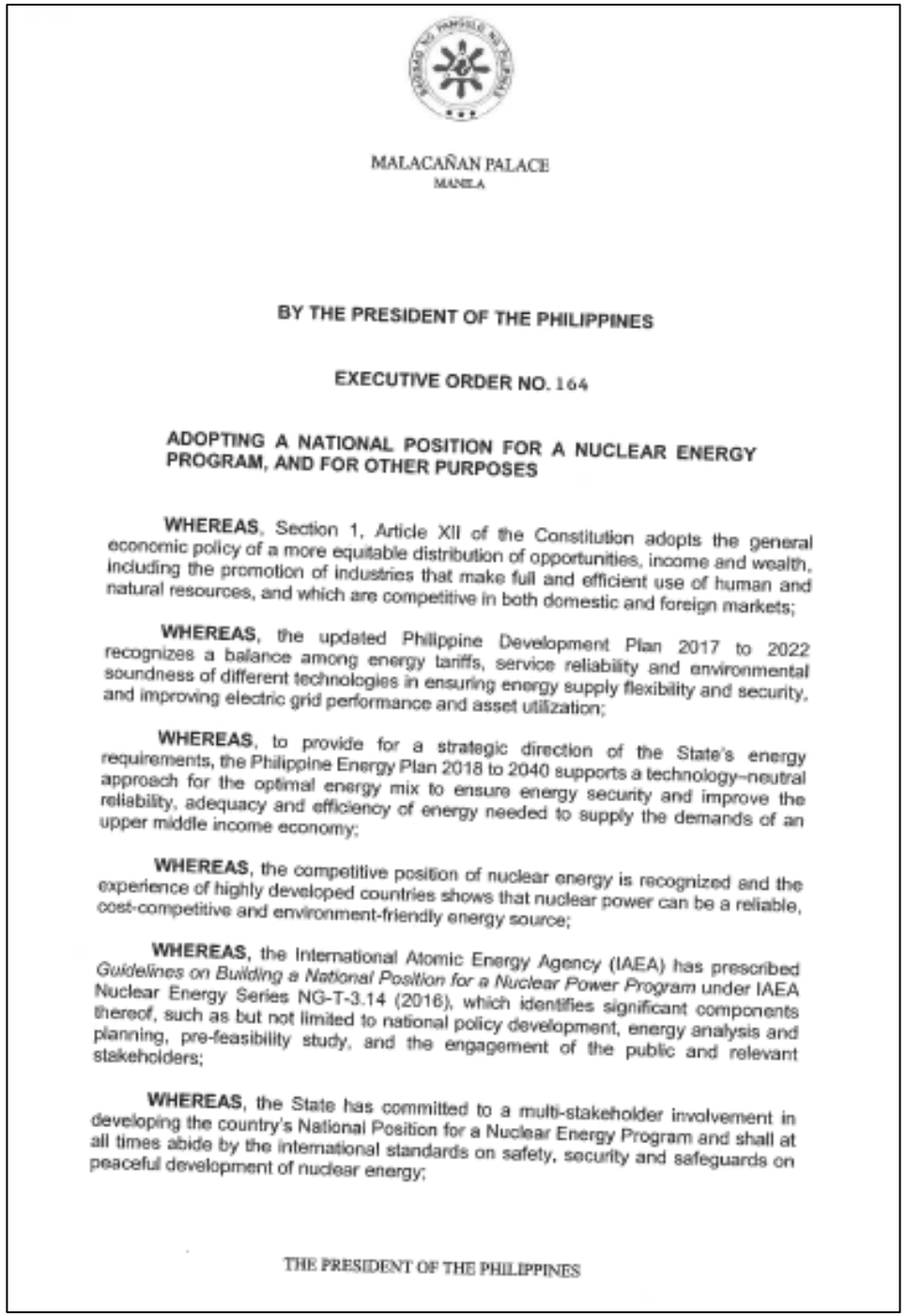
DEVELOPMENT OF NUCLEAR POWER INFRASTRUCTURE



NATIONAL POSITION ON NUCLEAR ENERGY

First requirement of a country embarking on a nuclear power program

- The most significant government action on nuclear since the construction and stoppage of the Bataan Nuclear power plant in the 1980's



MALACAÑAN PALACE
MANILA

BY THE PRESIDENT OF THE PHILIPPINES

EXECUTIVE ORDER NO. 164

ADOPTING A NATIONAL POSITION FOR A NUCLEAR ENERGY PROGRAM, AND FOR OTHER PURPOSES

WHEREAS, Section 1, Article XII of the Constitution adopts the general economic policy of a more equitable distribution of opportunities, income and wealth, including the promotion of industries that make full and efficient use of human and natural resources, and which are competitive in both domestic and foreign markets;

WHEREAS, the updated Philippine Development Plan 2017 to 2022 recognizes a balance among energy tariffs, service reliability and environmental soundness of different technologies in ensuring energy supply flexibility and security, and improving electric grid performance and asset utilization;

WHEREAS, to provide for a strategic direction of the State's energy requirements, the Philippine Energy Plan 2018 to 2040 supports a technology-neutral approach for the optimal energy mix to ensure energy security and improve the reliability, adequacy and efficiency of energy needed to supply the demands of an upper middle income economy;

WHEREAS, the competitive position of nuclear energy is recognized and the experience of highly developed countries shows that nuclear power can be a reliable, cost-competitive and environment-friendly energy source;

WHEREAS, the International Atomic Energy Agency (IAEA) has prescribed *Guidelines on Building a National Position for a Nuclear Power Program* under IAEA Nuclear Energy Series NG-T-3.14 (2016), which identifies significant components thereof, such as but not limited to national policy development, energy analysis and planning, pre-feasibility study, and the engagement of the public and relevant stakeholders;

WHEREAS, the State has committed to a multi-stakeholder involvement in developing the country's National Position for a Nuclear Energy Program and shall at all times abide by the international standards on safety, security and safeguards on peaceful development of nuclear energy;

THE PRESIDENT OF THE PHILIPPINES

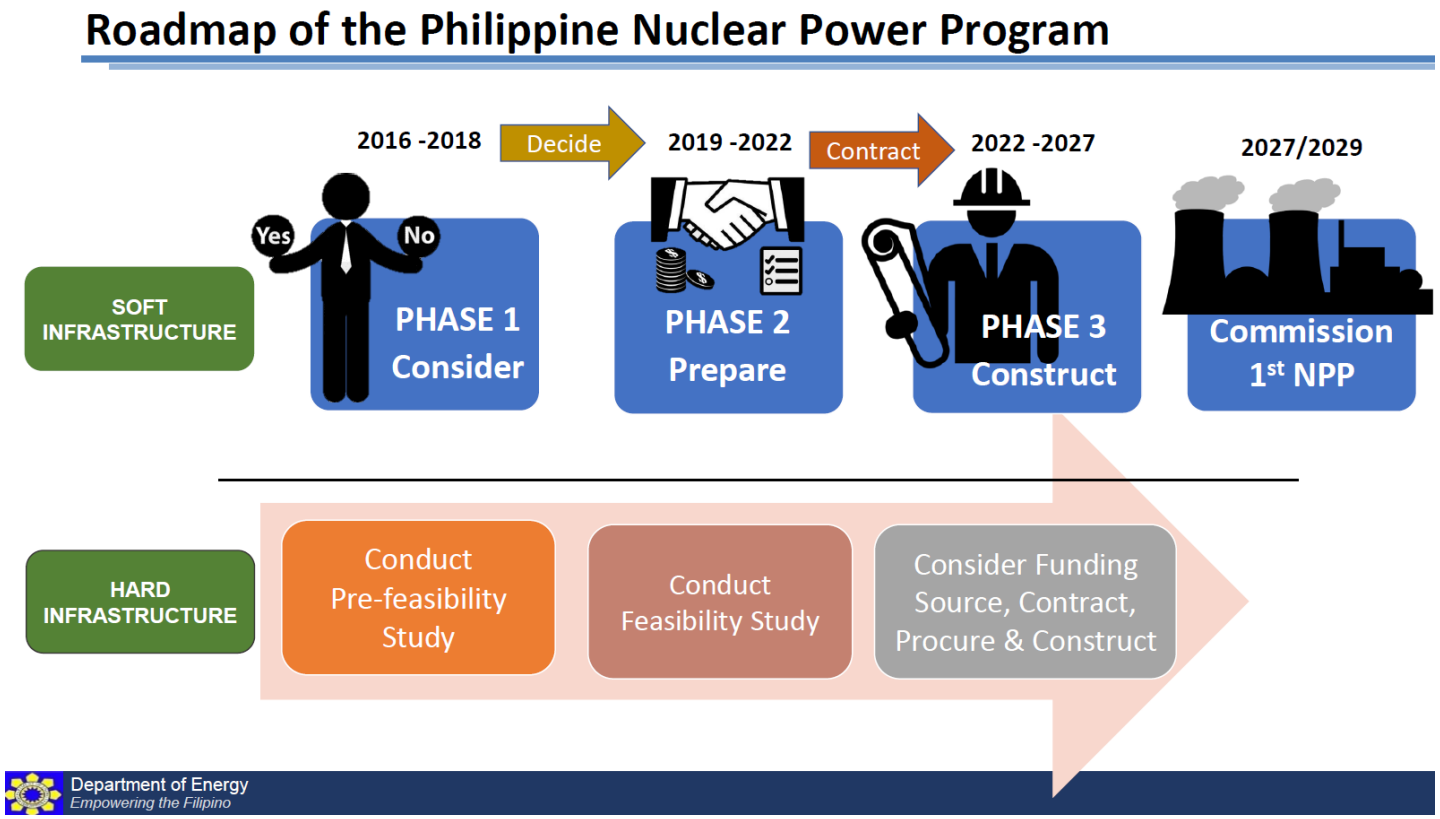
PRESIDENTS WANT NUCLEAR POWER

GMANETWORK.COM

Duterte hopes next administration will look into use of nuclear power

"We're not yet dito sa nuclear level but I hope the next administration would at least explore n...

OUTLINE (IAEA MILESTONES APPROACH)



ASEANTOM

ASEAN CAMBODIA 2022
ASEAN A.C.T.: Addressing Challenges Together

ACTIVITIES

Integrated Nuclear Infrastructure Review

- Identification of the 19 infrastructure issues outlined the following cornerstones:
  - **Policy**
  - **Legislative Framework**
  - **Public Acceptability**
  - **Alignment with International Standards**

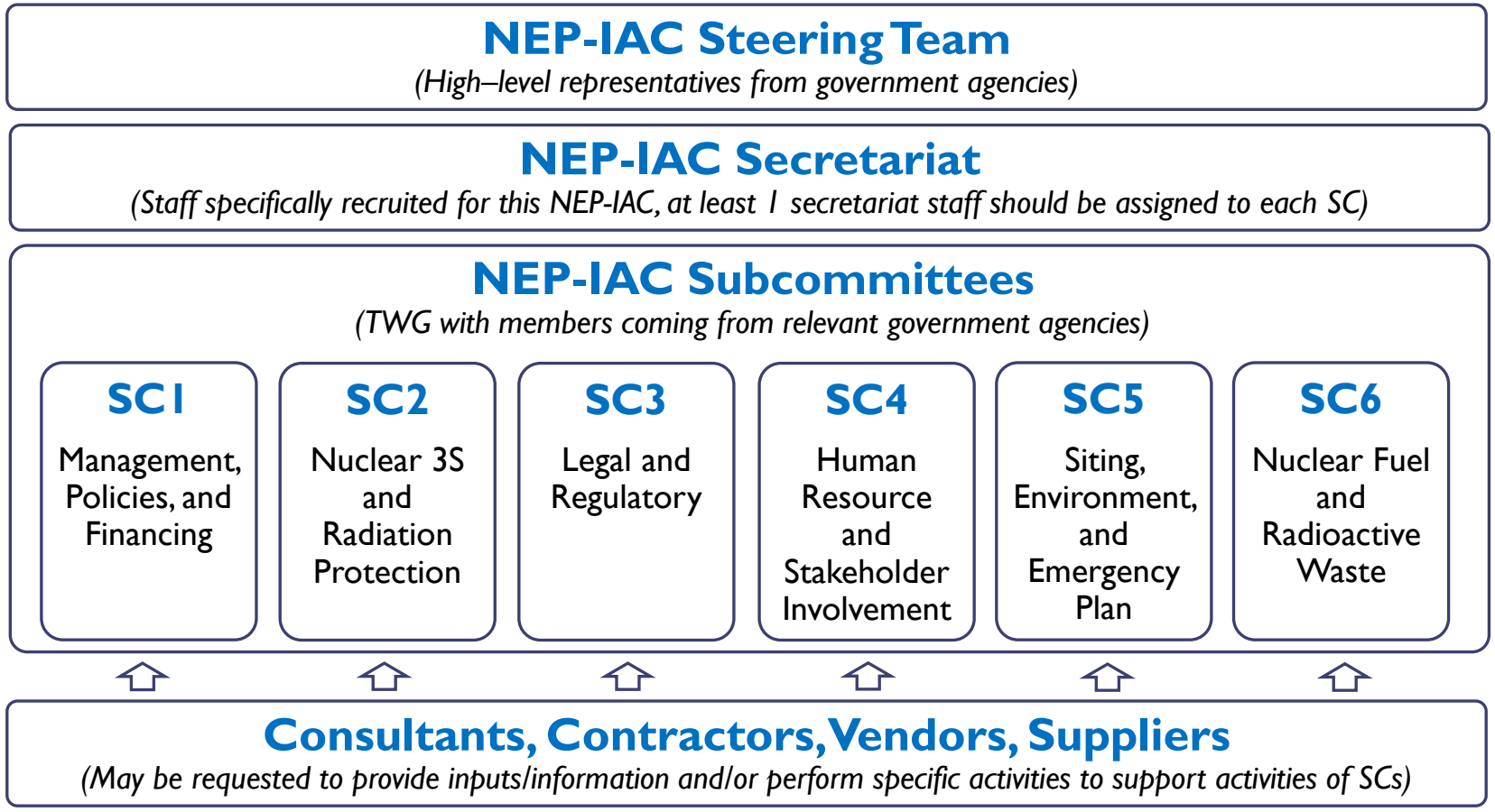
Integrated Work Plan

- A total of 19 activities were identified for the years;

  10 activities for 2020, 9 activities for 2021.
- The largest part of the activities relates to the
  - **National Position**
  - **Legal and Regulatory Framework**
  - **Human Resource Development**
  - **Stakeholders Involvement**

NEP-IAC STRUCTURE

E.O. 116, 2020



INTERNATIONAL ATOMIC ENERGY AGENCY: ATOMS FOR PEACE

Safety Standards Covered by the Review

And over 50 supporting Safety Guides

IAEA – INTERNATIONAL ATOMIC ENERGY AGENCY
U.N. ORGANIZATION – WORLD'S NUCLEAR WATCHDOG

Main theme:

Main theme: Atoms for Peace and Development

Repository of best practices for nuclear science and technology

Milestones Approach

Compiled 19 milestones approach for countries wanting nuclear power

Helps potential nuclear country through INIR (integrated nuclear infrastructure review) and IWP (Integrated work program) missions

NEP-IAC

Philippine INIR and IWP missions completed in 2018 and 2019

Needed work to be done re 19 milestones already delineated for follow-up work – this is the framework followed by NEPIAC

Special Congressional Committee on Nuclear Energy approved;
proposed by Cong. Sandro Marcos

PHILSTAR.COM

House creates special panel on nuclear energy

The lower house elected Rep. Mark Cojuangco (Pangasinan) as the chairperson of the 25-mem...

Passage of nuclear law to be championed by Congressman Mark Cojuangco, chair of new Congressional Committee on Nuclear Energy

https://youtu.be/_IpqfBn1Azl

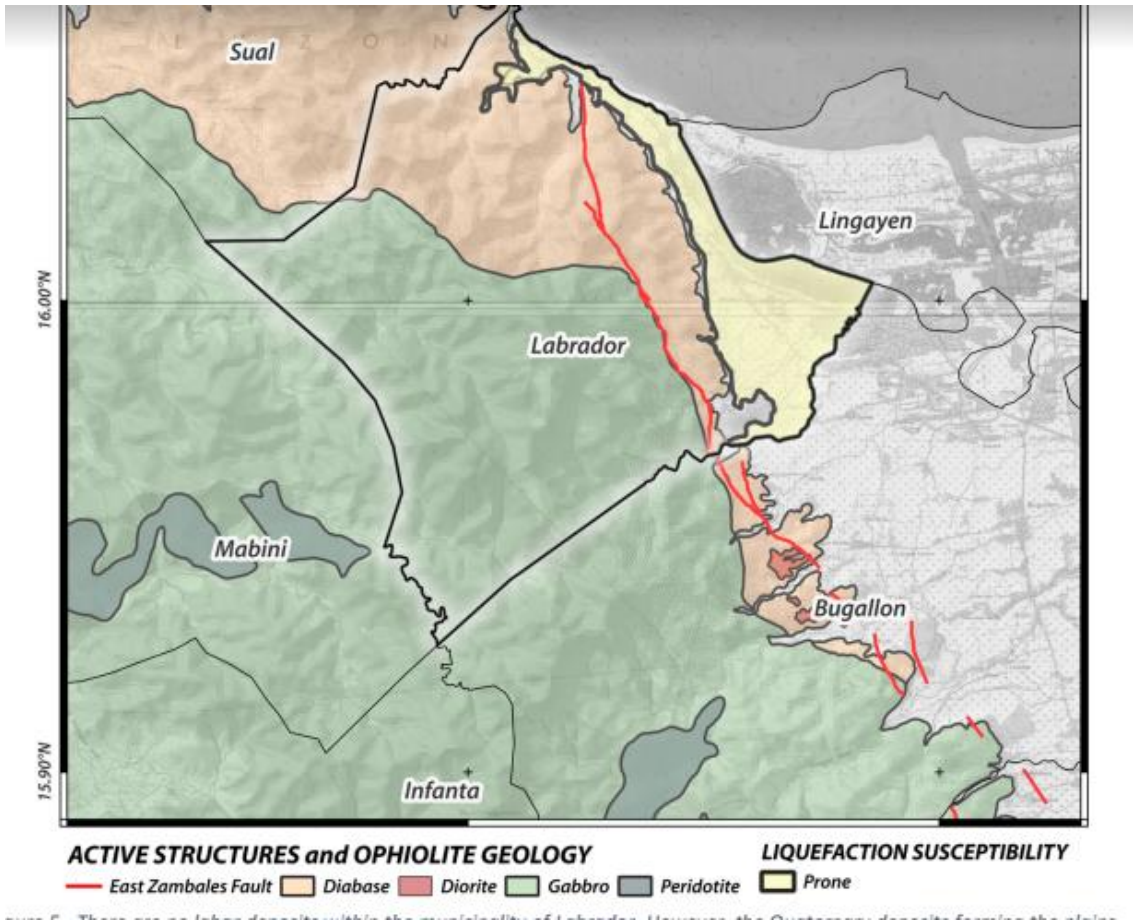
The Urgency and Imperative of Nuclear Electricity for the Philippines

YOUTUBE.COM

The Urgency and Imperative of Nuclear Electricity for the Philippines

Privileged Speech of HON. MARK O. COJUANGCO delivered in the House of Representatives

Pangasinan Town unanimously asking a Nuclear Plant to be sited in their vicinity!



Site exclusion report following IAEA GUIDES

PRELIMINARY NUCLEAR POWER PLANT SITING REPORT

For the Municipality of Labrador, Pangasinan

Selection of sites for nuclear installations requires extensive interdisciplinary studies encompassing geological, hydrological, environmental, engineering, social, and radiological impact assessments. These are described in several safety guidelines set by the international agency that governs nuclear facilities – the International Atomic Energy Agency (IAEA). The Philippines is one of the member states under this agency that benefit from these safety guidelines. Construction of nuclear power plants also falls under the siting for nuclear installation, and the considerations and general criteria are broadly explained in one of their publications on Safety Standards for Site Survey and Site Selection for Nuclear Installation under Specific Safety Guide (SSG) No. 35 (SSG-35) [1]. Under this guide, there are five stages relating to the safety considerations for the site of a nuclear installation, and the first step is the site survey process. In this site survey stage, large regions of interest are investigated to find potential

ASEANTOM

ASEAN CAMBODIA 2022
ASEAN A.C.T.: Addressing Challenges Together

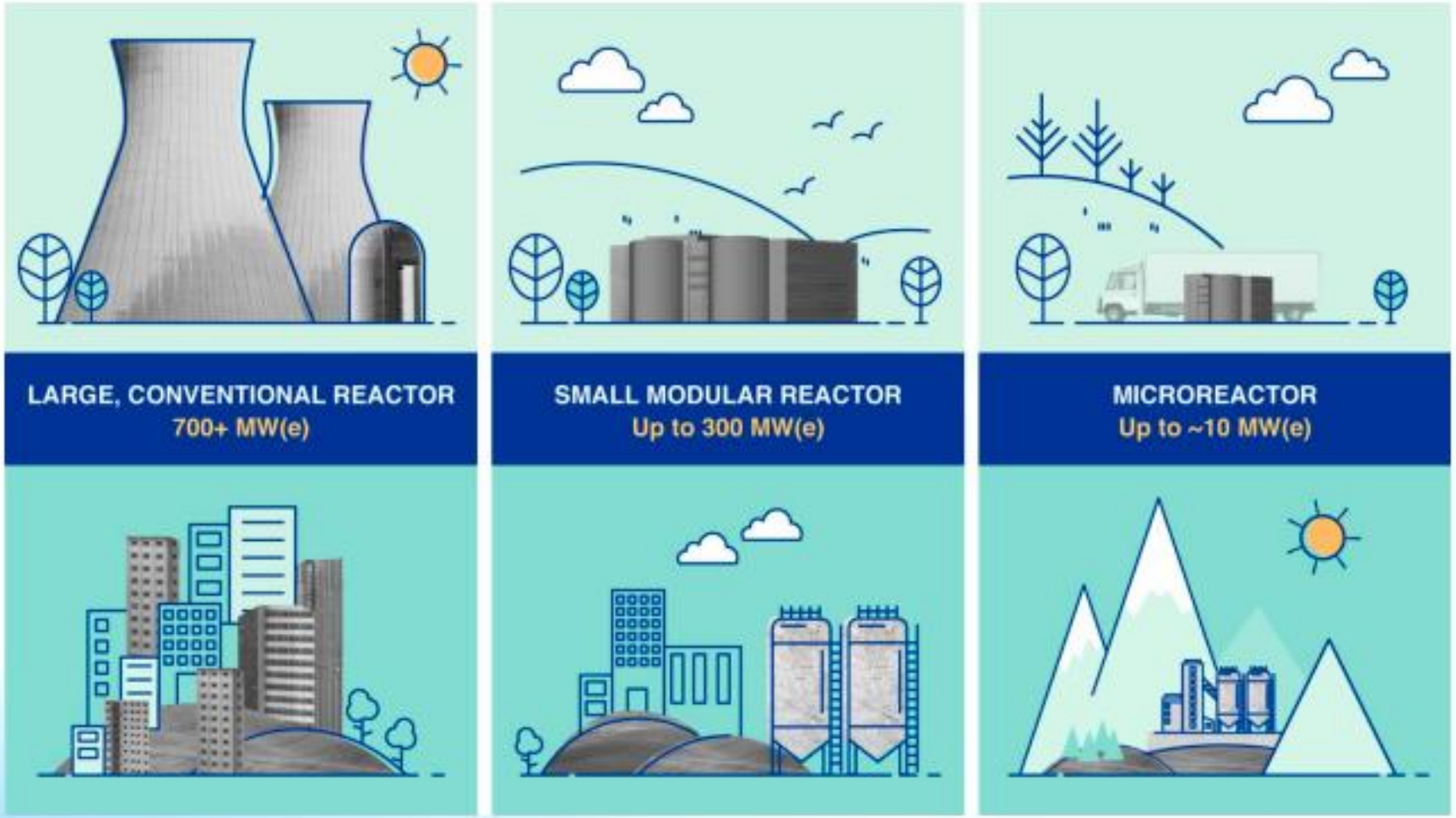
PNRI research reactor team after complete nuclear fuel loading. First TRIGA subcritical reactor worldwide. PROUDLY PINOY!!

PNRI restarts nuclear research reactor after 34 years

Safety, Security and Safeguards

Small Modular Reactor Definition

Advanced Reactors that produce typically up to 300 MWe, built in factories and transported as Modules to sites for Installation as demand arises.

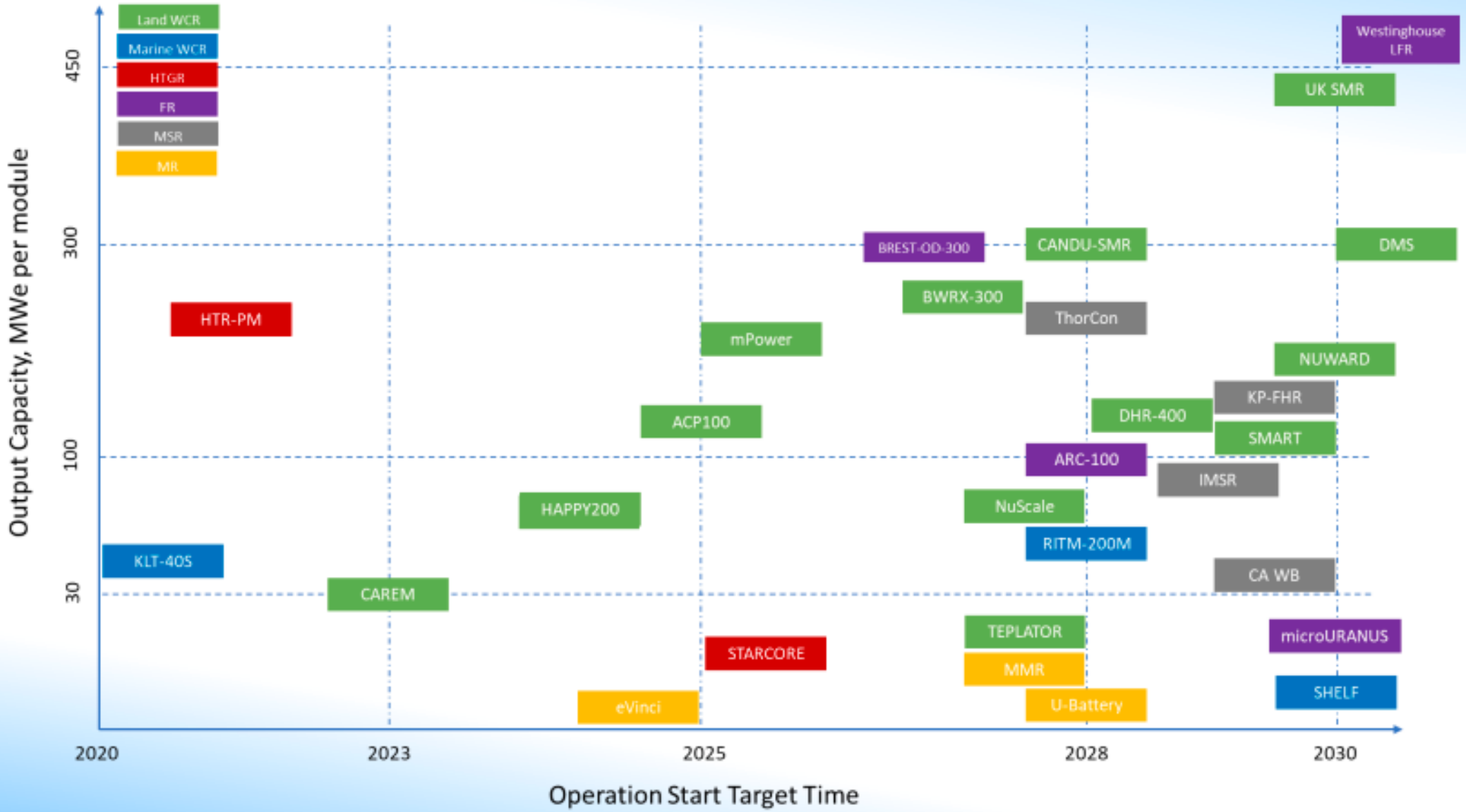


Small: in size, comparing to traditional reactors.

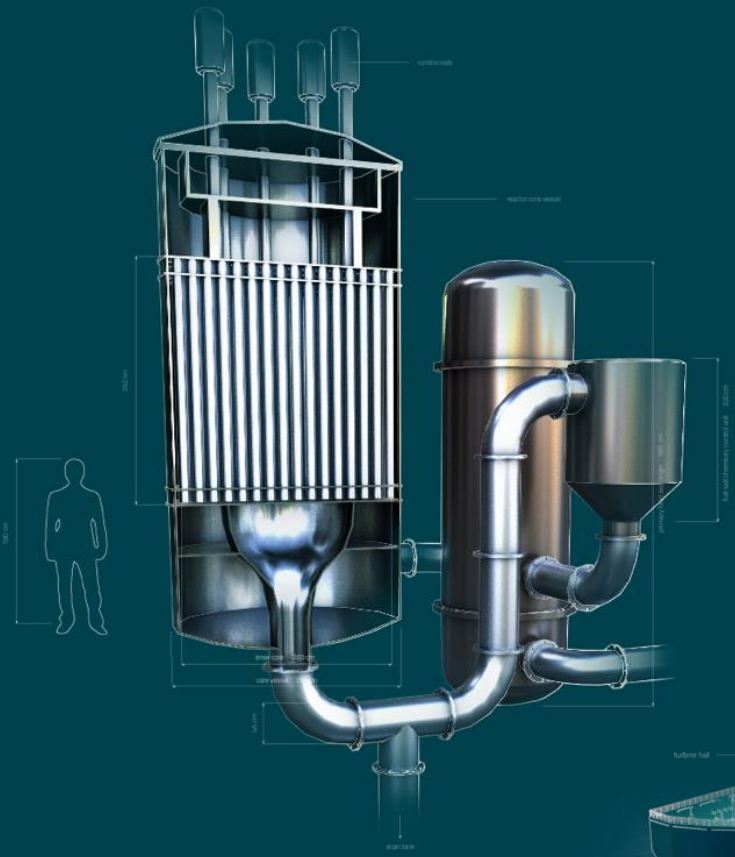
Modular: factory-manufactured, installed onsite.

Reactor: energy generation via nuclear fission.

SMR 10-year Deployment Horizon



THE CMSR POWER BARGE



Developing

The Compact Molten Salt Reactor

- Small modular nuclear reactor
- Mass produced
- Deployed on barges
- 3 years from order to grid
- Fully commissioned at Samsung shipyard
- 200-800 MWe power barges

SAFETY BY THE LAWS OF NATURE

Molten fluoride salt makes nuclear inherently safe

State of the art labs to perform fluoride and hydroxide salt experiments

The fluoride salt contains the radioactive elements

- No release of gases
- Very low solubility in water
- Below 490 °C, it is a rock
- Boils at 1500 °C
- CMSR operates at 600 °C – 700 °C

CSMR inherent safety:

- **Cannot** melt down or explode
- **Cannot** release radioactive gases to air or water
- **Cannot** be used for nuclear weapons
- Operates for **12 years without refuelling**

Site footprint/
exclusion zone

100 m

Emergency
planning zone

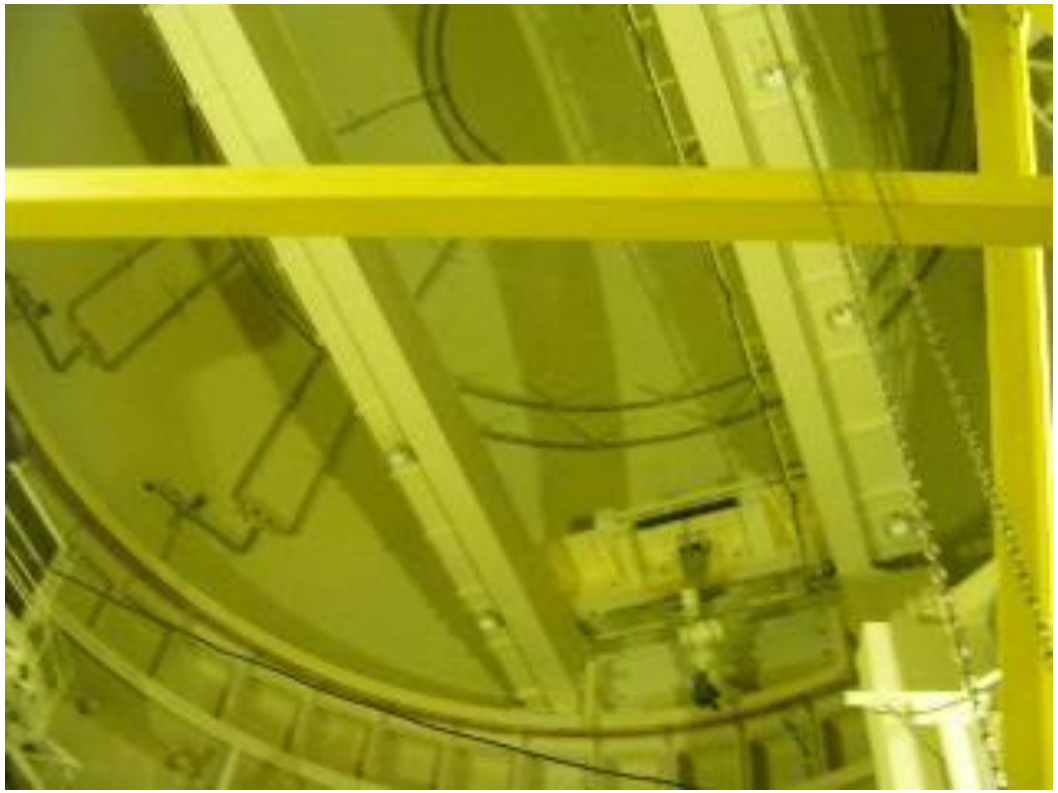
750 m

Bataan Nuclear Power Plant

Bataan Nuclear Power Plant

- Built at cost of US$ 2.3 billion
- Alleged corruption by 1st Marcos government AND Westinghouse Corporation
- Completed but closed nearly 35 years ago, mainly due to "safety reasons"--not 1 watt produced
- 3 exact operating models for more than 30 years – Korea, Slovenia and Brazil
- **Situated close to (or on) a "dormant" volcano and a fault – the recurring reason given why the plant was mothballed**


Westinghouse



Soviet	West
Converted weapon plant design	Built to commercial power plant
No containment (warehouse type building structure)	Containment (steel, air gap, concrete wall)
Graphite (flammable, fire)	Superalloys (meltdown)
Military civil management performed illegal experiment on a Civil power plant	Commercial plant not subject to equipment experimental trials
Closed system	International peer review
Positive reaction coefficient	Negative reaction coefficient

Korea has an EXACT copy of the BNPP Westinghouse Designed-plant that has been in operation since 1983

- no major accidents
- cost US $1 billion (compared to US 1.2 billion for BNPP)
- BNPP incorporated safety design lessons learned from Three Mile Island accident; KORI 2 did not
- Korean power rates are approximately half that of RP
- Korean Plant recovered in 7 years (lesser in RP)
- (note that $2.3 billion cost of Philippine nuclear plant is due to interest payments and absence of revenues from power generation)
- Korean nuclear engineers confident BNPP can be operated again

No Fear – Korea now has 23 NPP
has about half our electric rates

Research institute: South Korea offered to rehabilitate Bataan Nuclear Power Plant

By CNN Philippines Staff

Published Mar 6, 2022 8:50:30 PM

Latest from this section

Comelec exec hopes bill strengthening poll body will hurdle 19th Congress

Pharmally execs set to walk free from jail on June 2

SLOVENIA HAS ANOTHER EXACT MODEL OF BNPP IN KRSKO
Operating nearly 40 years, very profitably and safely (1/10 cost of PHL power)

Krsko Slovenia nuclear power plant cross section and photo. Going inside this 40 yr old safe, profitable operations brings bittersweet thoughts-- what if we had run ours ?

Like Comment Share

BNPP URANIUM FUEL WOULD LAST 18 MONTHS--IF BNPP WERE A 620 MW COAL PLANT:

coal

50 Panamax ships

Importation cost = USD 600 million

nuclear

1 jeepney

USD 20 million

Is there a Fault **Beneath** the Bataan Nuclear Power Plant? A systematic study using Electrical Resistivity, Seismic Refraction and Radon Gas Detection

By

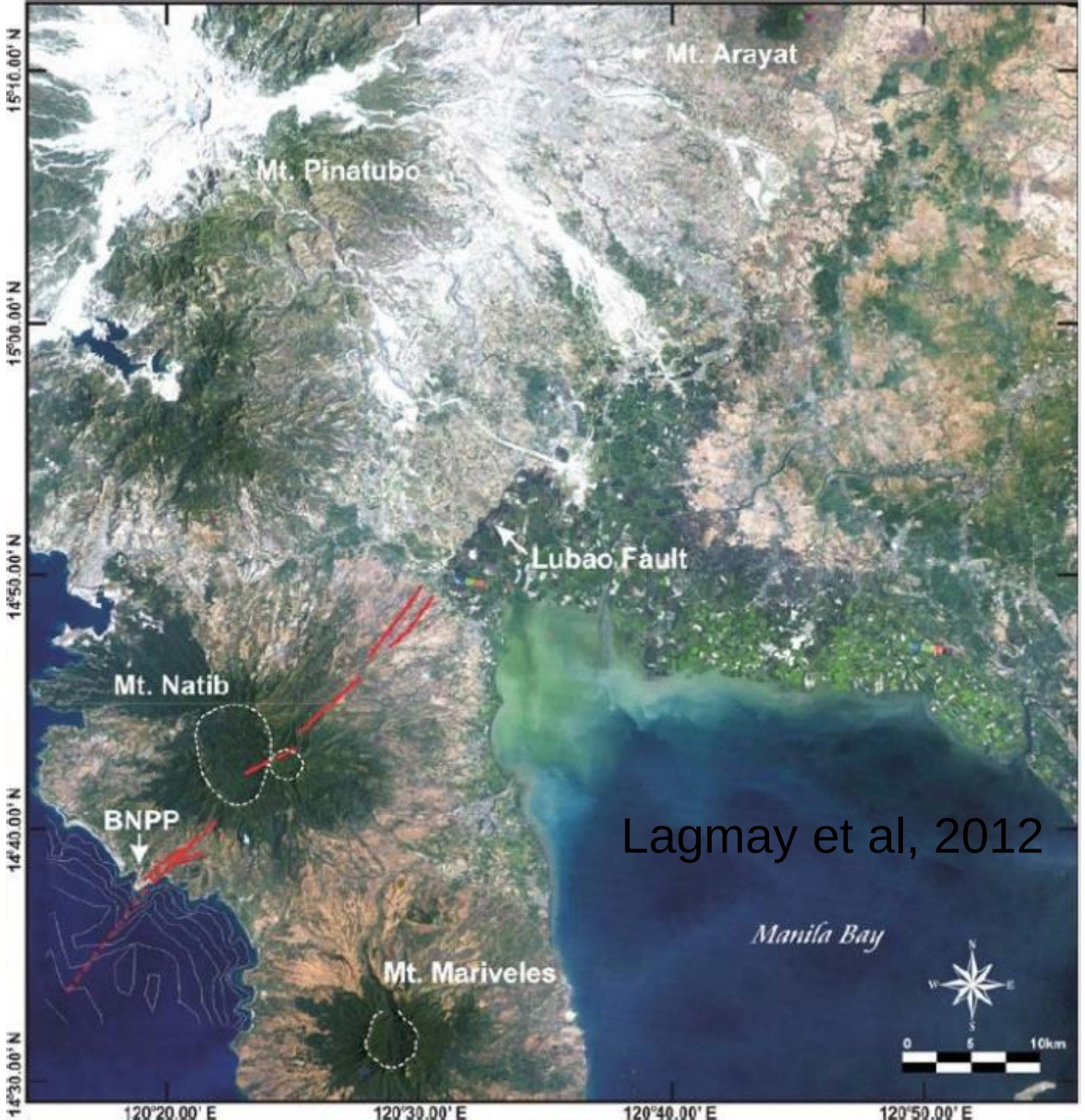
Dr. Carlo A. Arcilla, Richard Jason Antonio

Mario Collado

Benjamin Punay (RIP)

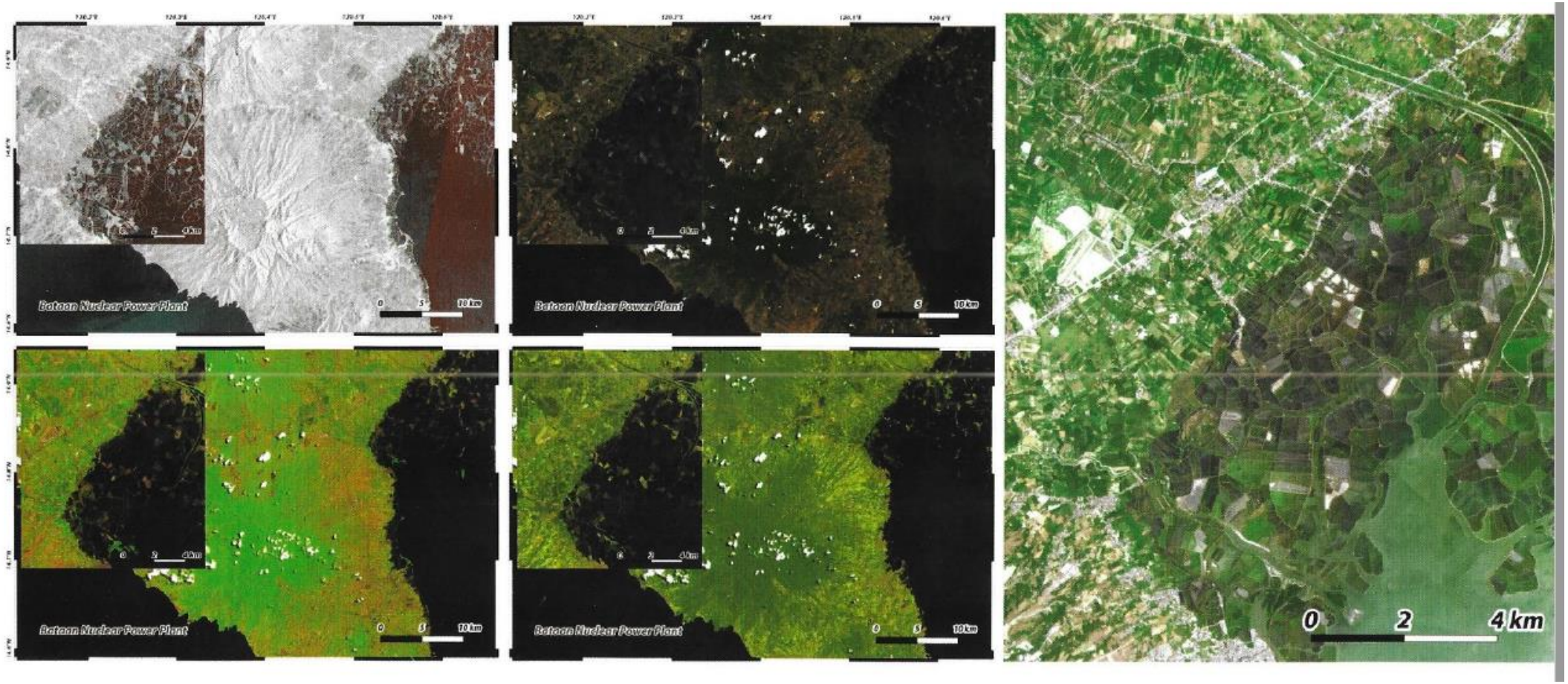
This study only aims to test if the BNPP is located ON TOP of an active fault

- It does not seek to study location of faults BESIDE or CLOSE to the structure (covered by engineering design?)
- **An active fault BENEATH the BNPP will condemn the structure immediately AND absolutely.**



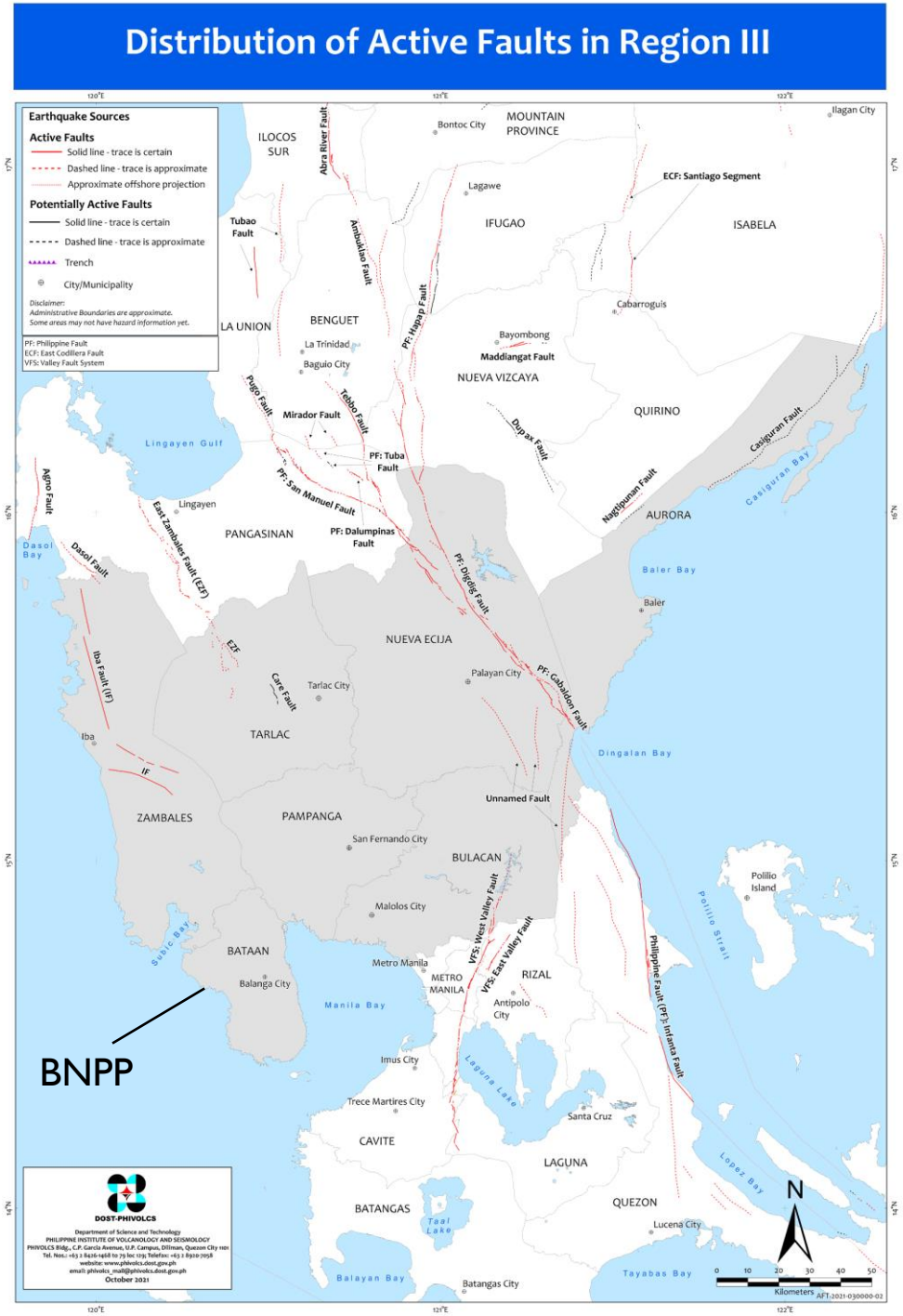
Lagmay et al, 2012

Natib satellite photos – "fault" could be land-use difference (Sentinel & Planetscope)



Active Faults

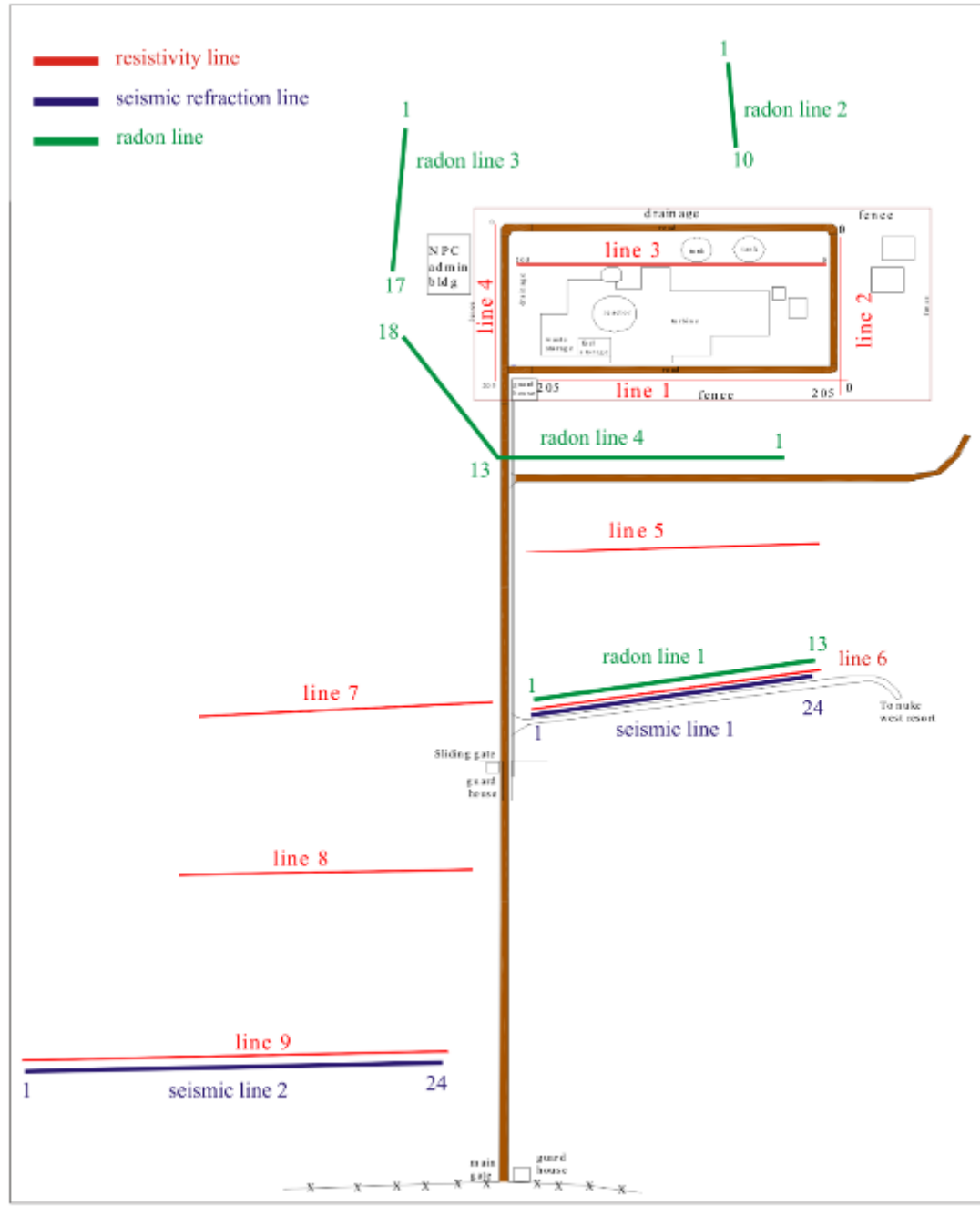
- By definition, *active faults MUST have surficial manifestations* (e.g., stream displacements, damaged structures, etc.)
- The active fault map of the Philippines by PHIVOLCS **does not** list an active fault in the vicinity of the BNPP



Examples of structures with faults beneath them

Methods

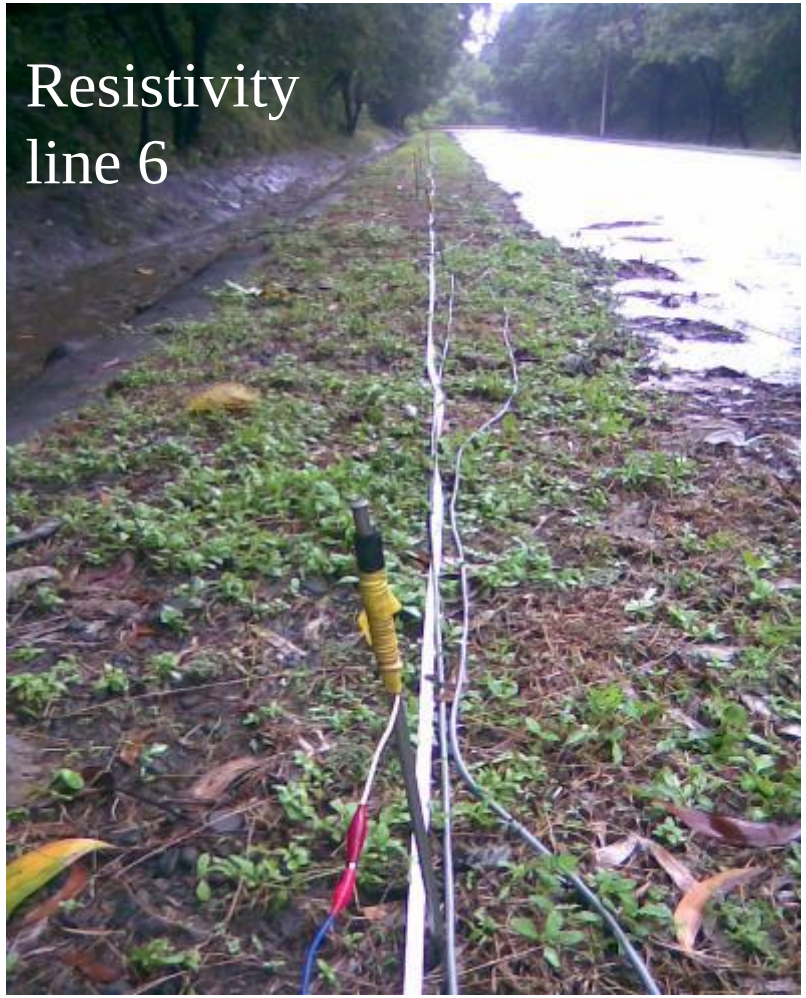
- Electrical Resistivity (Mario Collado)
- Seismic Refraction (Benjamin Punay)
- Geochemical Fault detection by Radon gas survey (with Jason Antonio, Peter Zamora, Tina Petrache)


resistivity line
seismic refraction line
radon line
radon line 2
1
10
radon line 3
1
17
18
NPC admin bldg
drainage
fence
line 3
line 4
line 2
line 1
205
fence
205
radon line 4
1
13
line 5
radon line 1
13
1
line 6
24
seismic line 1
1
line 7
Sliding gate
guard house
line 8
line 9
1
seismic line 2
24
main gate
guard house

Field measurement

Resistivity

Set of instrument used



Resistivity line 6

Summary

- NINE (9) lines of electrical resistivity were laid out along the perimeter of the Bataan Nuclear Power Plant to determine if there is a fault beneath the building. Using close-spaced electrodes in a Wenner array, the four 2-D electrical resistivity sounding profiles show NO evidence of faults underneath the Bataan Nuclear Power Plant

The seismic refraction data
strongly support the findings
of the electrical resistivity surveys:
No faults are detected
beneath the BNPP

Radon and Thoron soil gas testing:

Geochemical detection of hidden faults
(another independent test)

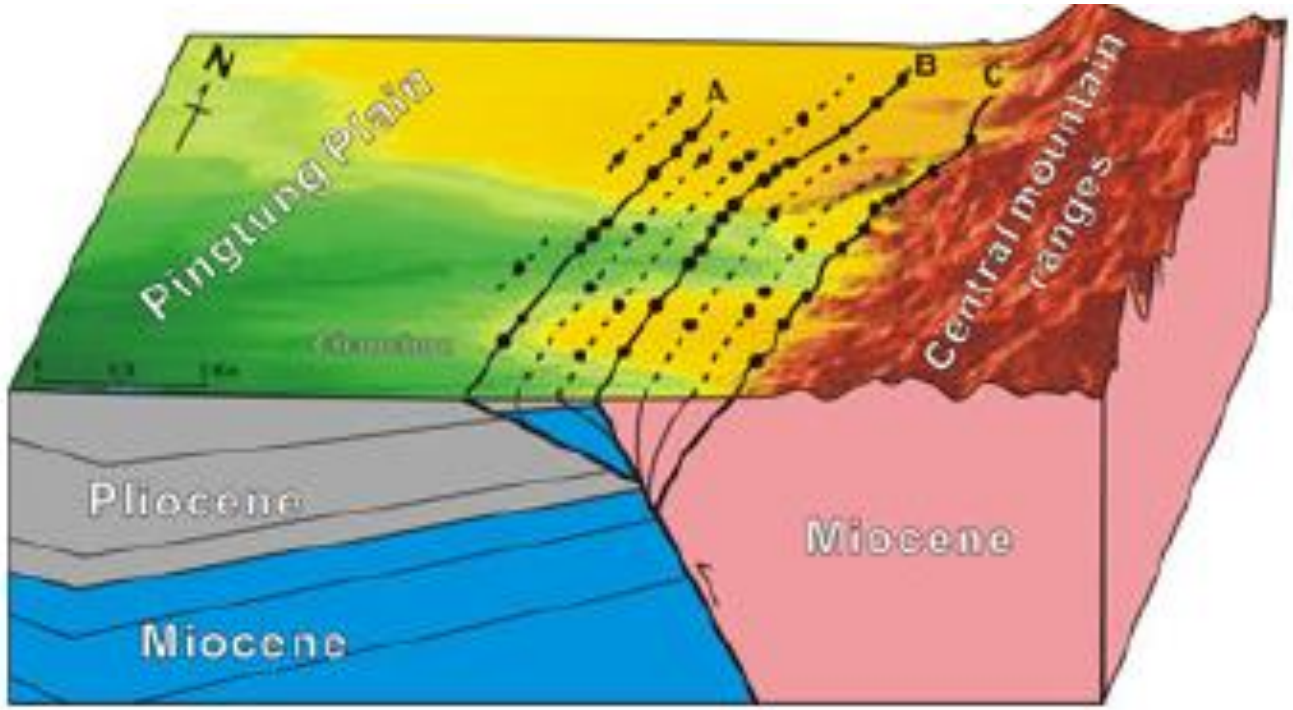
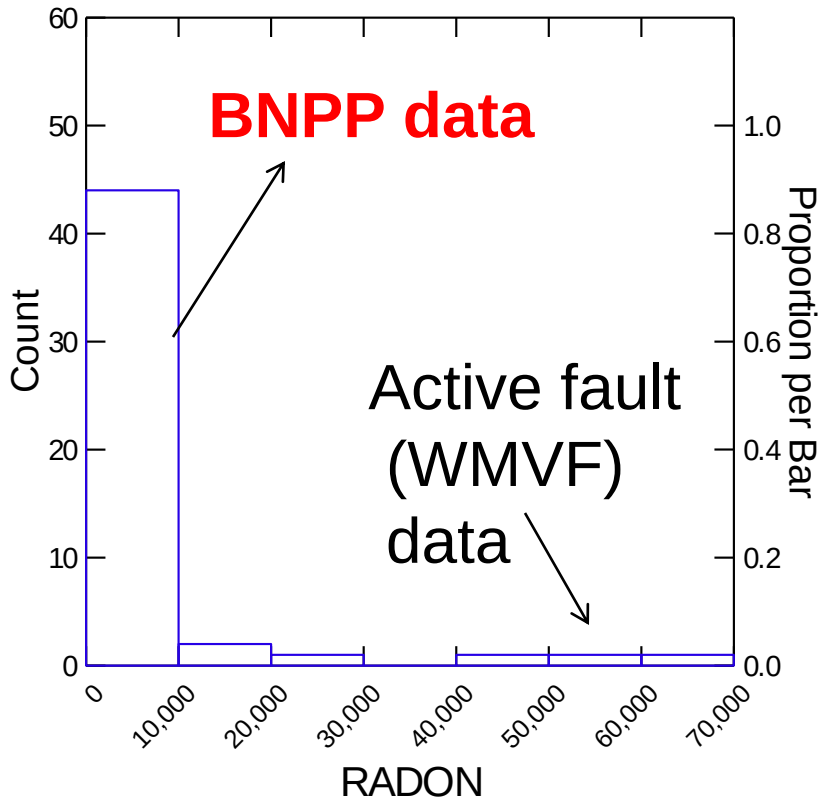


Fig. 5. Example for the delineation of the surface trace of a fault zone by soil gas survey in southern Taiwan (modified from Fu *et al.* 2005). Black circles indicate the sites with anomalous soil concentrations; those sites can delineate the surface traces of the faults/fractures.

Yang et al., 2008

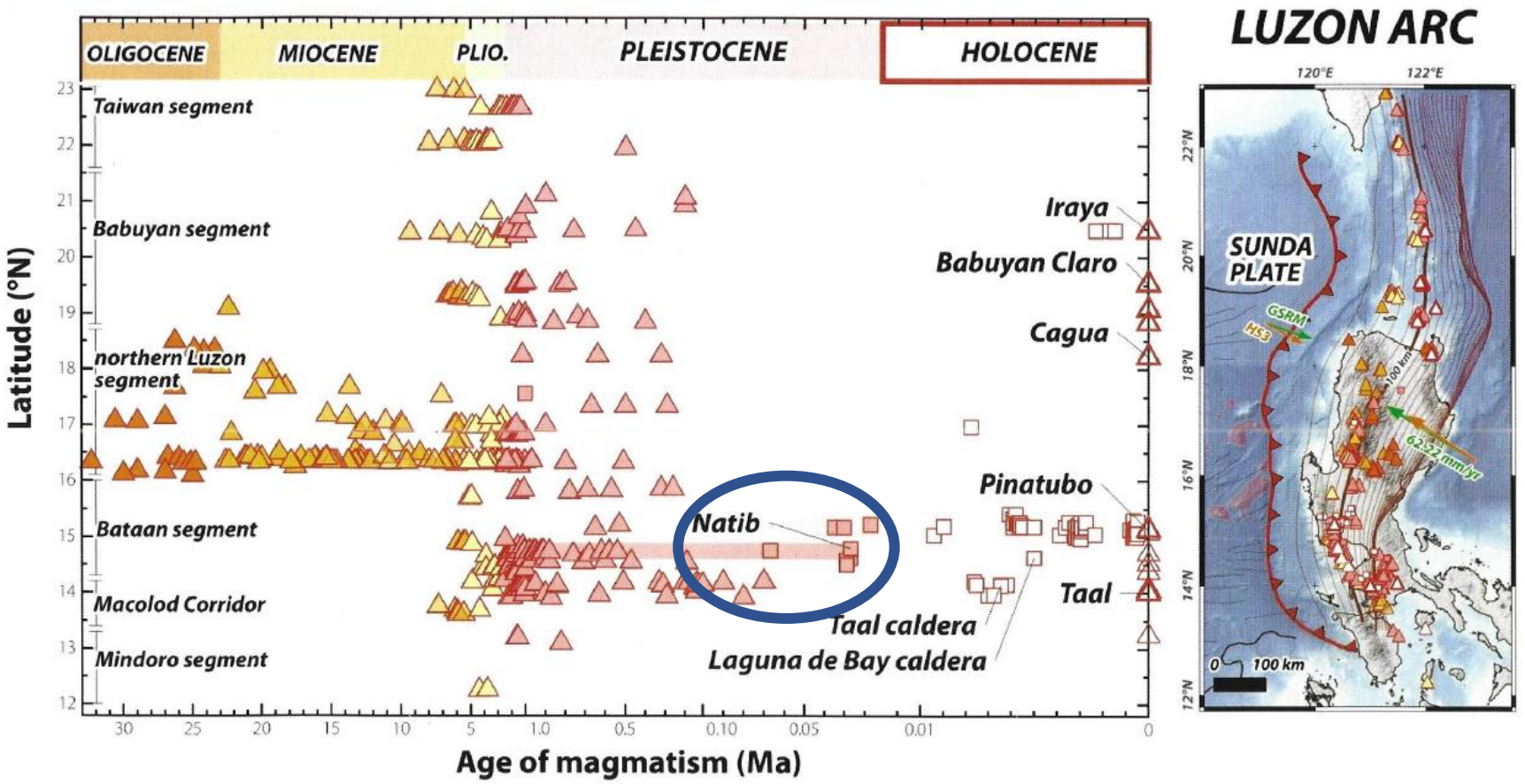


WMVF – West Marikina Valley Fault
Arcilla et al, 1987

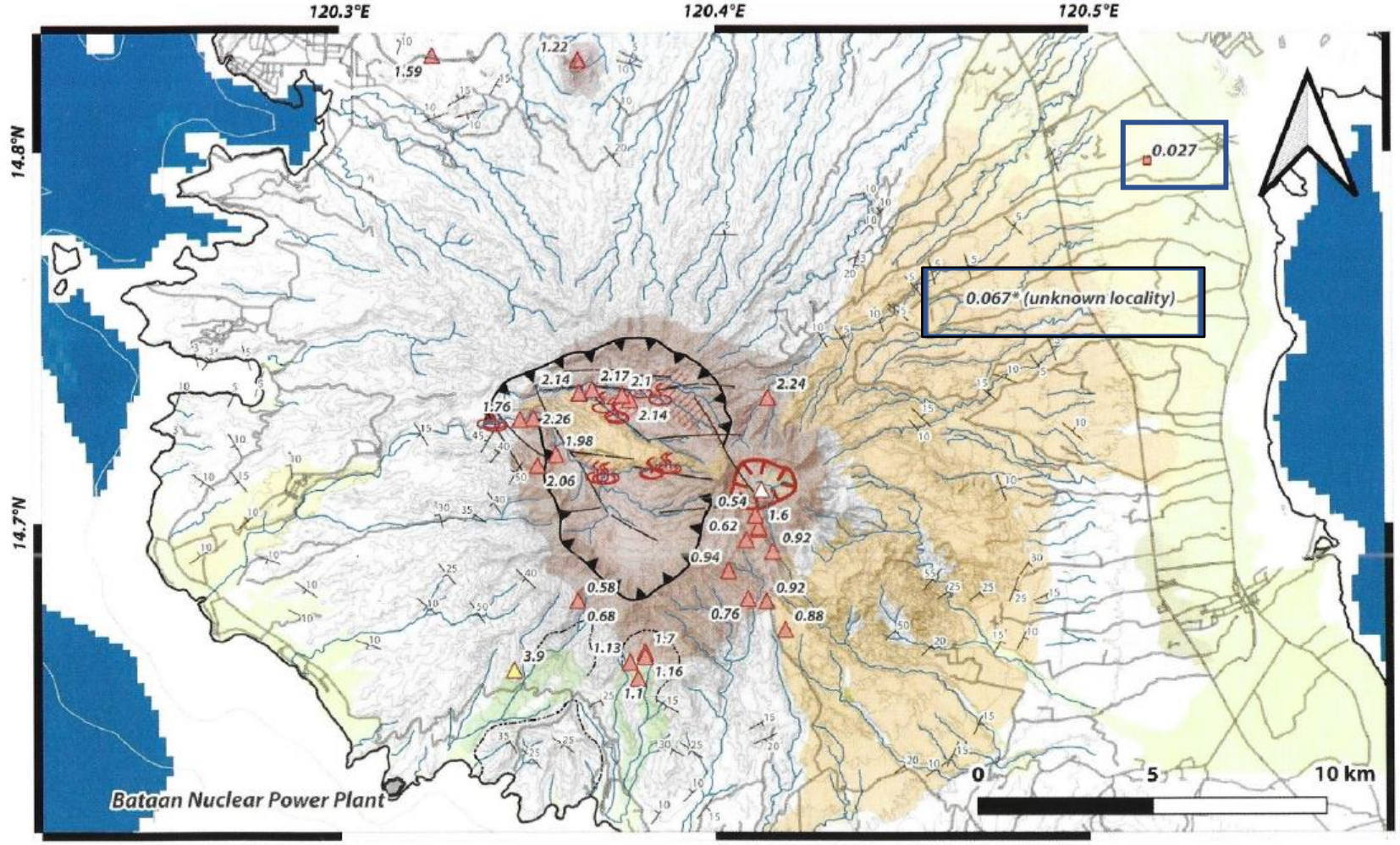
Volcanic Risk

- Age of the volcano in question
- Pyroclastic flows from Mt Natib have been mapped very close to the BNPP
- ONLY TWO reliable age dates :
  - 27,000 (14C, known location) and 67,000- 69,000 years (fission track) Currently searching and testing for charcoal from latest eruption.

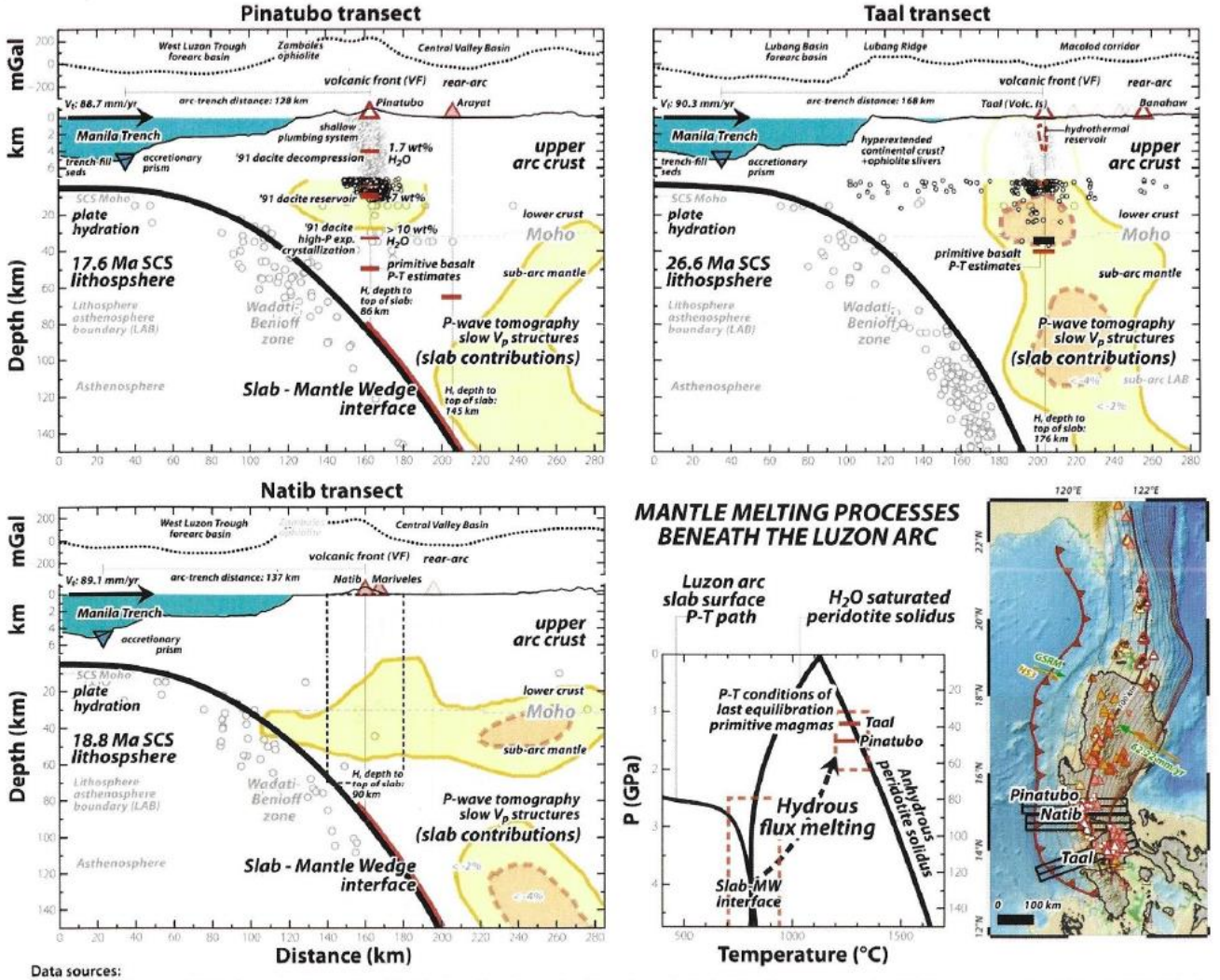
Ages of Philippine Volcanoes



Mt. Natib volcanic age and geology



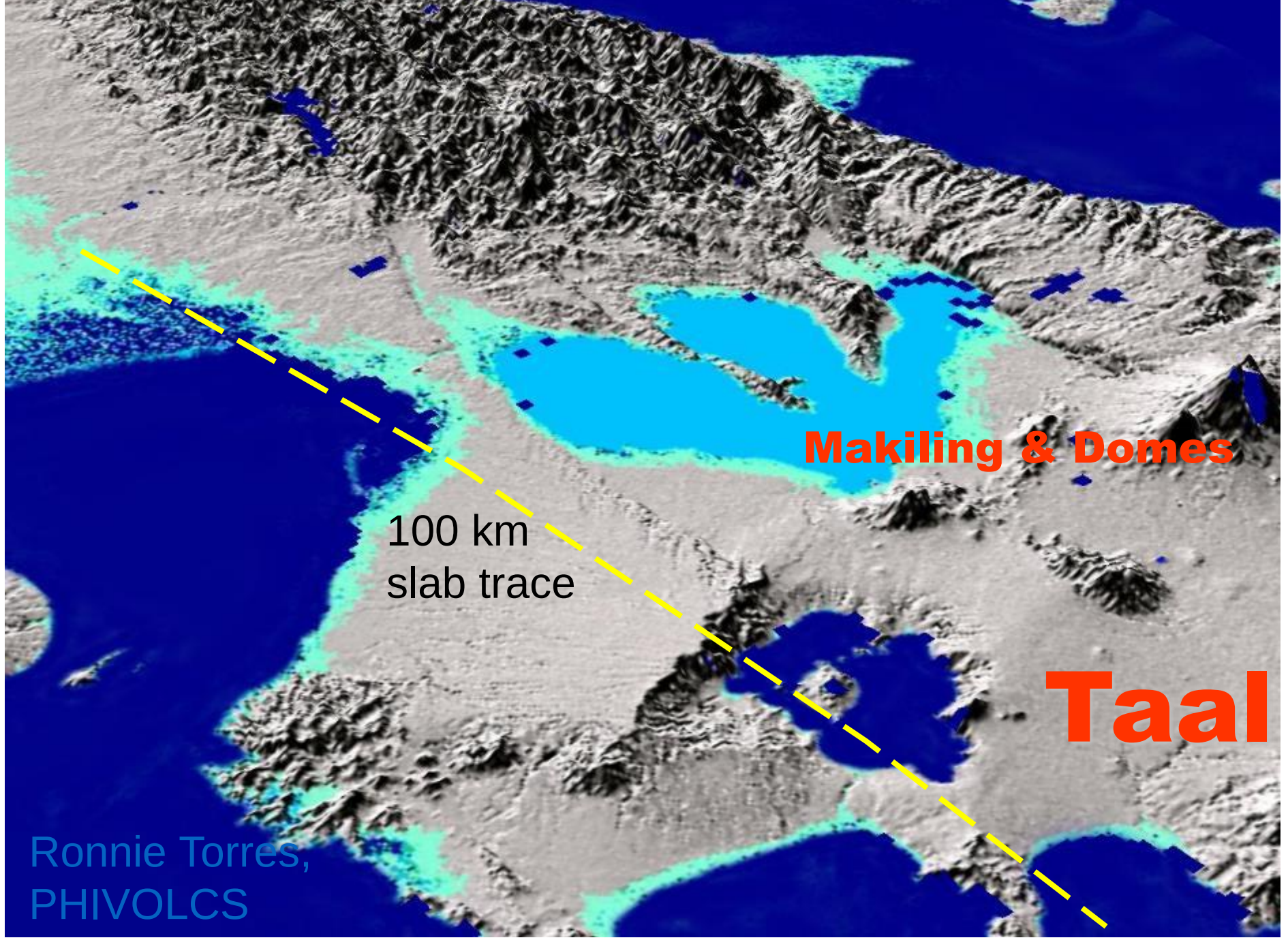
No volcano seismicity beneath Natib, vis-à-vis very active seismicity beneath Pinatubo and Taal



Data sources:
Slab depths- Hayes et al. 2018, Elevation- Sandwell and Smith 2014, Free-air gravity- Bonvalot et al., 2012, Seismicity- Ramos et al. 1999, You et al. 2013, Engdahl et al. 2020, Seismic tomography and magnetotellurics - Sevilla 2011, Alanis et al. 2015, Subductiong seafloor ages- Seton et al. 2020, Crustal and lithospheric thickness - Besana et al. 1995, Laske et al. 2013, Alfonso and Salajegdeh 2019, SU-PSP plate velocity- DeMets et al. 2010, Petrologically-derived P-T conditions - Arcilla 1998, Rutherford and Devine 1996, Scaillet and Evans 1999, Prouteau and Scaillet 2003, Borisova et al. 2005, Peridotite solidii: Hirschmann 2000, Till et al. 2011, Grove et al. 2012, Slab P-T path: Syracuse et al. 2010

Metro Manila and volcanoes

- >10 million people within 50 km radius of a Laguna de Bay volcanoes, which is YOUNGER than Mt. Natib, and much more explosive in the past
- Located < 80 km Taal volcano, which is active, and most deadly Philippine volcano
- Most of city is built on pyroclastic flows from Laguna de Bay volcanoes


Makiling & Domes
100 km
slab trace
Taal
Ronnie Torres,
PHIVOLCS


Magic Moments
San Miguel
WOODCRAFTS
& GIFT SHOP
ROYAL
COMMUNICATION CENTER
Wobbly
AMERICA HOTEL

Manila and Clark would not have passed risk criteria imposed by earthquake and volcanic factors!

- If we follow the (defective) reasoning for closing the Bataan Nuclear Power Plant, then the cities of Manila and Angeles (Clark) should have never been built in the first place.

Closure of nuclear facility was very painful economically

- Single largest debt item of the Philippines
- A poor country until April 2007paying $180,000 per day just on interest payments
- Resulted in crippling power failures in the 1990s with untold economic losses
- Crippling power failures opened floodgates to maze of independent power suppliers which has made power very expensive

COMPARING HISTORICAL GDP AND GDP GROWTH RATES WITH A COUNTERFACTUAL THAT ASSUMES BATAAN NUCLEAR POWER PLANT OPERATION, 1988-1993 (JOSEF, 2022)

Table 2. Comparing historical GDP and GDP growth rates with a counterfactual that assumes Bataan Nuclear Power Plant operation, 1988–1993.

Year	GDP growth rate	GDP in constant prices (PhP, base year 2018)	Counterfactual GDP growth rate	Counterfactual GDP in constant prices (million pesos, base year 2018)	Actual GDP in US$ (million)	Counterfactual GDP in US$
1988	6.8	4,813,453.58				
1989	6.2	5,112,143.35	6.2	5,112,143.35	42,575.18	42,575.18
1990	3.0	5,267,397.42	5.0	5,367,750.52	44,311.59	45,155.81
1991	-0.6	5,236,934.24	3.0	5,528,783.04	45,417.56	47,948.63
1992	0.3	5,254,614.29	3.0	5,694,646.53	52,976.34	57,412.69
1993	2.1	5,365,818.07	4.0	5,922,432.39	54,368.08	60,007.87

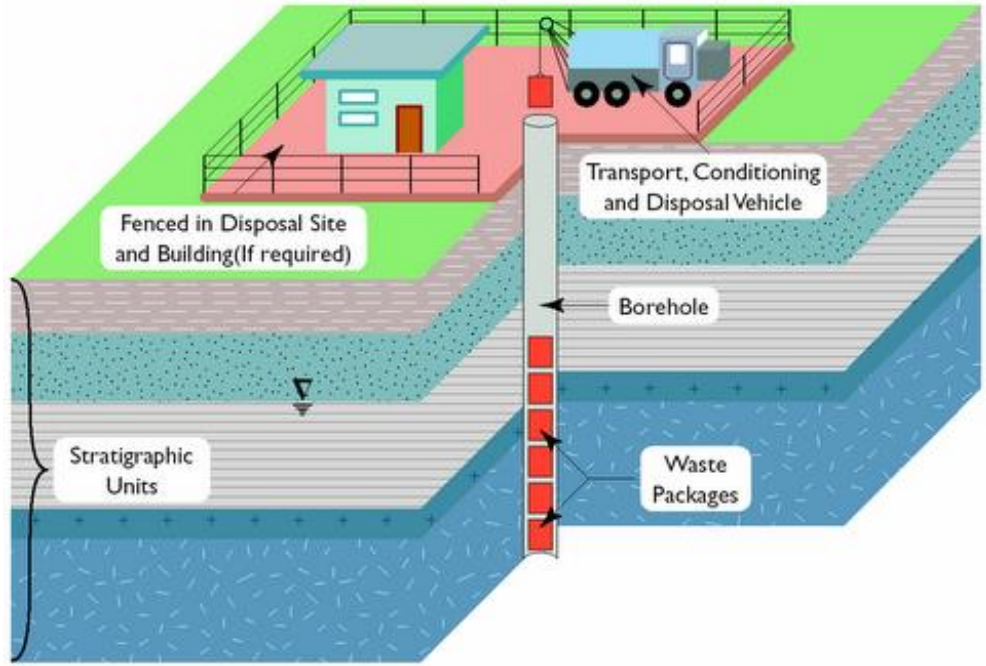
Source of basic data: *World Bank* (*2020*).

Needed: a detailed geologic study of Mt. Natib

- LIDAR mapping
- Geologic mapping
- Geophysical studies
- Radiometric dating
- Multidisciplinary and wide range of geologists local and worldwide
- Basis for safety assessment for operation of BNPP

Nuclear Waste Management

Borehole technologies



Nuclear waste: Achilles heel of nuclear has technological solution for PHL – deep boreholes

- PHL has technology to drill >2km deep boreholes (from geothermal industry)
- Place waste inside boreholes and plug with bentonite, which will prevent nuclides from reaching surface and groundwater
- Select an isolated island as borehole site which can adequately store ALL future waste SAFELY.

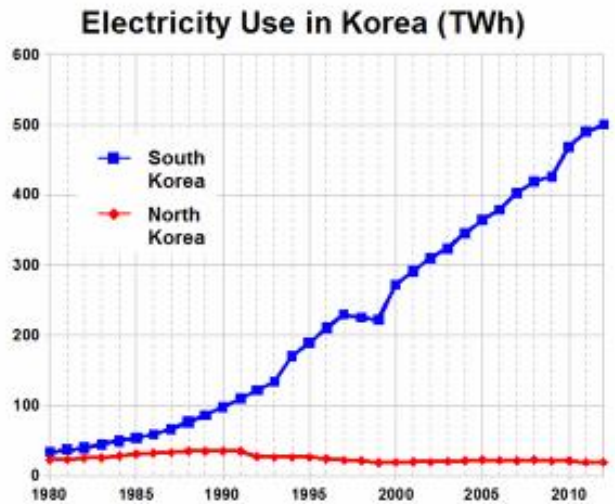
Deep borehole disposal in an isolated island

Nuclear Energy in Korea

- 24 reactors provide about one-third of South Korea's electricity from 23 GWe of plant.
- South Korea is among the world's most prominent nuclear energy countries, and exports its technology widely. It is currently involved in the building of the UAE's first nuclear power plant, under a $20 billion contract.
- Nuclear energy has been a strategic priority for South Korea, but the president elected in 2017 introduced a policy to phase out nuclear energy over some 45 years.
- The new president, Yoon Suk-yeol, elected March 2022, has pledged to scrap this policy.

Operable Reactors	Reactors Under Construction	Reactors Shutdown
		
23,091 MWe	5,360 MWe	1,237 MWe

Changes made by Nuclear Power



~ 30 times more power generation than DPRK

Korea on Philippine Nuclear

Thoughts on Philippine Nuclear

- ❑ **Philippine has Big Island Luzon**
  - Luzon has Similar Size of Land and Population of South Korea
  - Why not Benchmark Korea's successful Nuclear Program
- ❑ **Philippine has many Small Islands**
  - SMR such as SMART100
- ❑ **Why Thinking Korea as Best Partner**
  - Reactor Lineup
    - APR1400, 100MW SMART, ~600MW i-SMR, Even Research reactor…..
  - Fully Established Supply Chain
  - NPP Operation more than 40 years
  - Success in UAE and Jordan JRTR construction
  - We Kept Promise on-time and in-budget
- ❑ **Important: Just Do It rather than Only Planning……**

Challenges

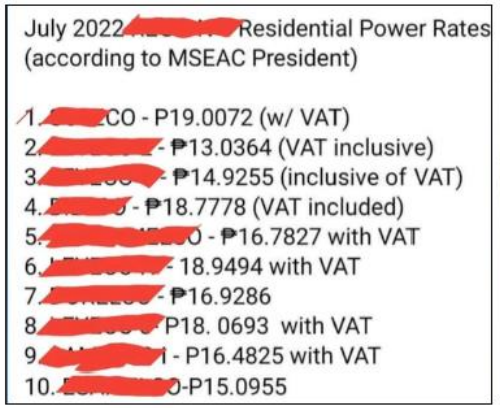
- How to integrate nuclear harmoniously with coal, LNG and other energy players; new nuclear build MUST HAVE electricity buyers
- SMR ownerships should be shared with electric cooperatives to lower electricity costs
- Stakeholder concerns about locating new nuclear power plants “in their backyards”
- Mitigating regulatory and legislative challenges
- Rapid expansion of depleted nuclear human resource base

THE CHALLENGES UNDER THE PRESENT POWER INDUSTRY LANDSCAPE

- EC Franchise are expiring
- Astronomical Cost of Power
- Frequent Power Outages

National Electrification Commission

Certificate of Franchise



July 2022 Residential Power Rates (according to MSEAC President)

1. CO - P19.0072 (w/ VAT)
2. - ₱13.0364 (VAT inclusive)
3. - ₱14.9255 (inclusive of VAT)
4. - ₱18.7778 (VAT included)
5. - ₱16.7827 with VAT
6. - 18.9494 with VAT
7. - ₱16.9286
8. P18. 0693 with VAT
9. - P16.4825 with VAT
10. -P15.0955

Nuclear Program Needs an Empowered
Nuclear Energy Program Implementing Organization

- Strong political will and leadership to forge nuclear program
- Sufficient nuclear contribution to lower electricity rates
- Needs teamwork between DFA and NEPIO in dealing with vendor countries and their regulations
- Nuclear law passage and amendment of laws (e.g. EPIRA) to allow nuclear into the energy mix
- Negotiations with countries to explore Malampaya extension to buy time for nuclear

Availability of scholarships for PhD in nuclear science and engineering

PhD Program

Select a graduate program in a good university anywhere in the world

Get accepted to their PhD program

Recommendation

Ask recommendation from **caarcilla@pnri.dost.gov.ph**

We will ask for FULL FUNDING FOR SCHOLARSHIP from Science Education Institute (SEI)

Slots are still available!