European Conference of Defence and the Environment

ECDE 2024

MAGNUS SPARREVIK
Norwegian Defence Estates Agency

EUROPEAN
CONFERENCE OF
DEFENCE AND THE
ENVIRONMENT

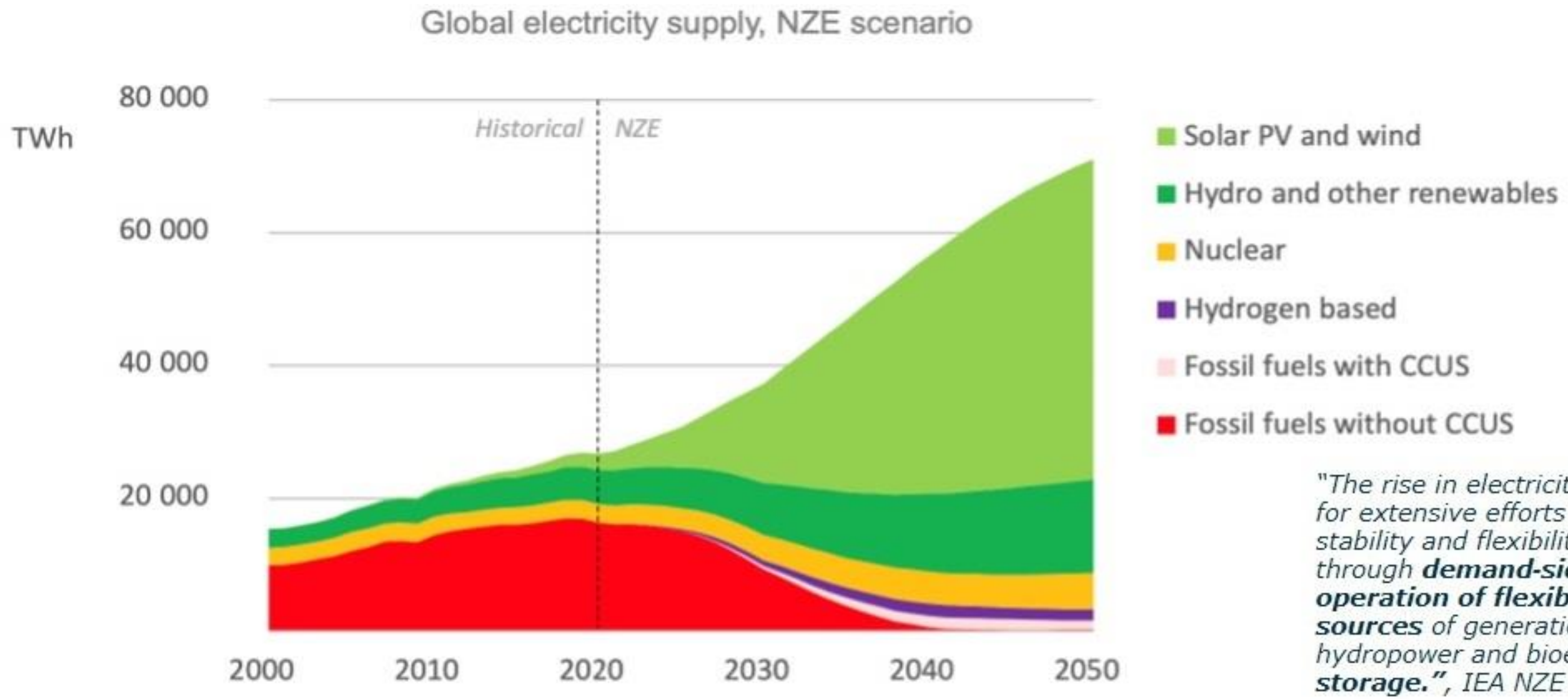
FORSVARSBYGG

Norwegian Defence Estates Agency

Introducing renewable energy in a defence context

Magnus Sparrevik, Senior adviser,
Norwegian Defence Estates Agency

EUROPEAN CONFERENCE OF DEFENCE AND THE ENVIRONMENT



"The rise in electricity demand also calls for extensive efforts to ensure the stability and flexibility of electricity supply through ***demand-side management****, the* ***operation of flexible low-emissions sources*** *of generation including hydropower and bioenergy, and* ***battery storage."****, IEA NZE by 2050 Roadmap*

In our net zero pathway, renewables make up nearly 90% of electricity generation in 2050, propelled largely by solar PV and wind


Buildings
Mobility
Operation

European Conference of Defence and the Environment

ECDE 2024

INGELA BOLIN HOLMBERG
FMV Sweden

EUROPEAN CONFERENCE OF **DEFENCE** AND THE **ENVIRONMENT**

Adaptation and Mitigation of Climate Change

Productmanager Ingela Bolin Holmberg

FMV

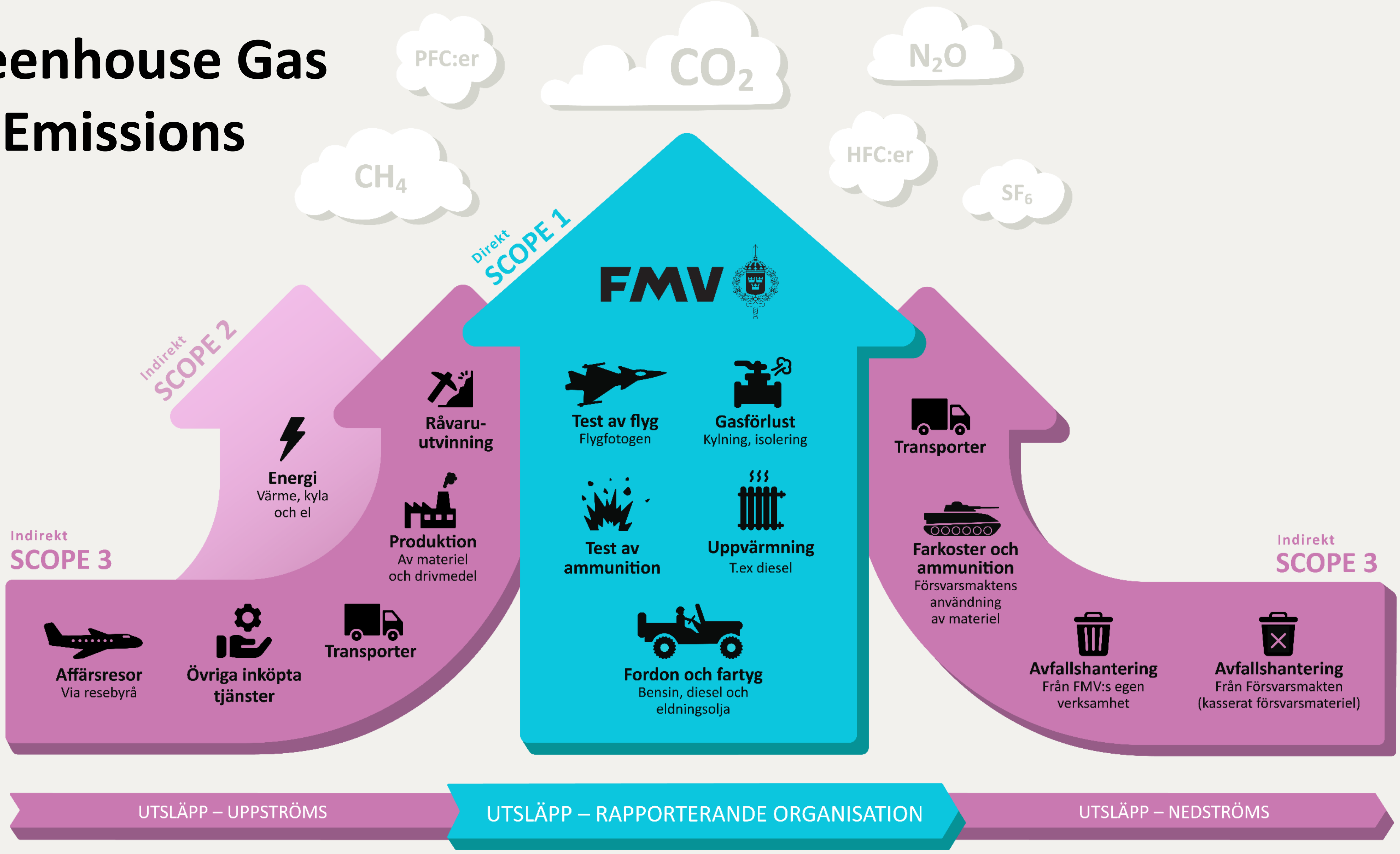
Swedish Defence Materiel Administration (FMV)

Delivering the right equipment for a stronger defence

- FMV is responsible for procuring defence materiel for the Swedish Armed Forces
- FMV assists the Armed Forces in the early stages of planning of new materiel capabilities, solutions and options
- FMV conducts testing and evaluation of technical systems for the Armed Forces

FMV

Greenhouse Gas Emissions



FMV

U.S. AIR FORCE

UNITED STATES NAVY

Biojetproject (SAF)

2013-2020

Bilateralt collaboration between Sweden (FMV) and USA (US Air Force och NAVAIR)

New Biojetfuelprocess fulfull the jetfuel specification without blending fossil jetfuel

ATJ:

- Alchol To Jet , with aromatic compounds based on fermented wood

CHJ:

- Catalytic Hydrothermal Conversion Jet, with aromatic compounds based on fatty acid esthers

FMV

Qualificationprocess ASTM D4054

Tier 1

Specification Properties

Tier 2

Fit-For-Purpose Properties

Tier 3

Component/Rig/APU Testing

Tier 4

Engine Testing

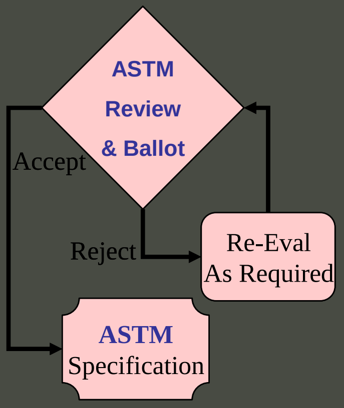
CHJ-SKA qualified 2019

ATJ-SKA qualified 2023

ASTM Research Report

Boeing
Honeywell
Rolls-Royce
AIRBUS

OEM/FAA Review & Approval



ASTM Balloting Process

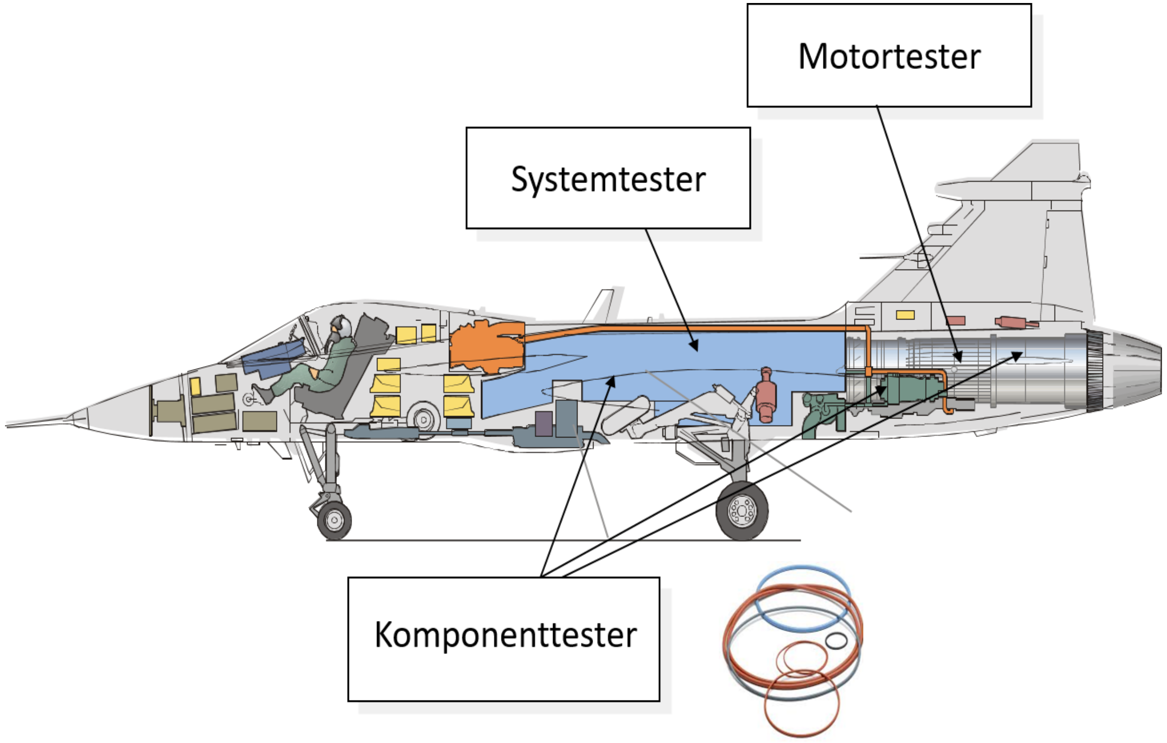
ASTM INTERNATIONAL
Standards Worldwide

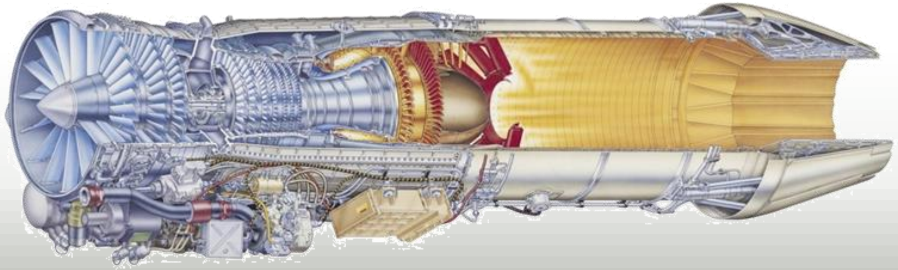
ASTM D7566 Specification

FMV

Preparation for demonstrationflight for Gripen fighter

- Material analyze
- Component test
- Systemtest
- Enginetest





September 2016

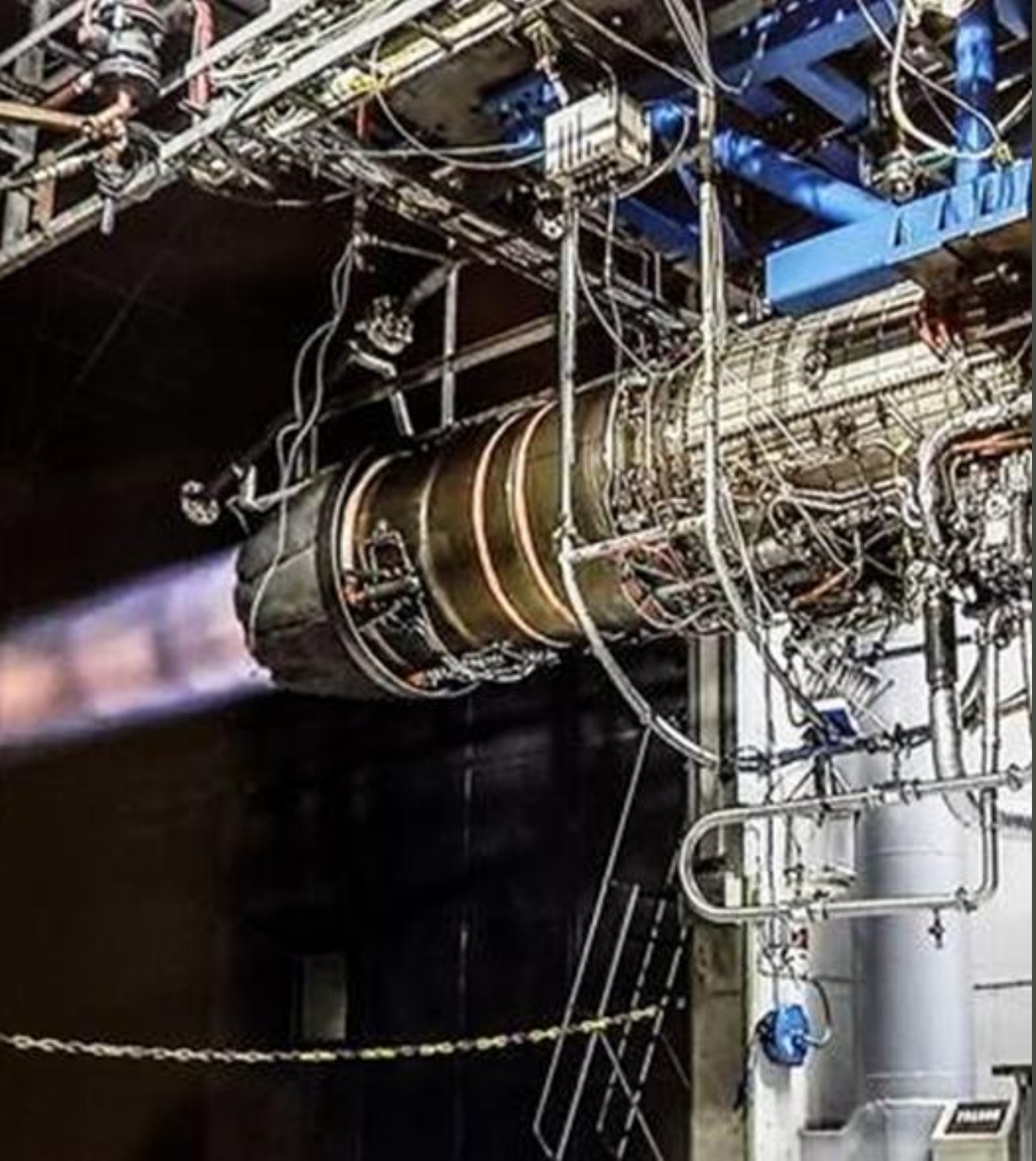
First demonstrations flight with **Hornet** med 100% biojet CHJ

NAVAIR qualification of CHJ
as part of Green Fleet Program

March 2017

First demonstrations flight with **Gripen** with 100% biojet CHJ

FMV



Enginetest ATJ SKA

Combustor rig testing; GE, US

Engine Component Rig Testing; Wet rig test GE, US

Combuster rig Testing, GKN, SWE

FMV

Summary of Biojetproject

- The flights show that flying on a Biojet is feasible
- Defence Agency/Industry have built up competence to understand how to use/accept biojet for Swedish military Aircraft
- Gripen Fighter is now approved to use biojet according to ASTM D7566
- Biojet project has also been input to Swedish Armed Forces study and cooperation with other Agencys in Sweden

FMV

NATO STO AVT-397

Sustainable Aviation Fuel (SAF) in military context

<u>Objectives:</u>

1. To obtain SAF certification (at 50%) on all NATO vehicles (flying and non-flying platforms)
2. To maintain interoperability between the Nations and the deployment bases
3. To reinforce the links between National certification authorities and OEMs

<u>Topics covered:</u>

Certified and emerging SAF, difference civil and military aviation certification, deployment (infrastructure and logistic requirements)

Members: BEL, CAN, CZE, DEU, DNK, FRA, GBR, GRE, ITA, NLD, POL, PRT, SWE, TUR and USA (+ AUS)

Military aspects to consider for SAF

ASTM D4054 civil qualification process for SAF

- 8 process qualified, more to come
- Faster evaluation in future process

Military aspects to consider:

- After burner (engine)
- Extreme environment
- Inflight refueling
- Flight envelope
- Elastomers
- Flexible tanks
- Storage
- Additives
- Single Fuel Policy, SAF for military diesel engines
- Logistic, mixing different process in the future

FMV

Green procurement as a tool to promote circular economy and reduced greenhouse gas emissions

FÖRSVARETS MATERIELVERK | FMV

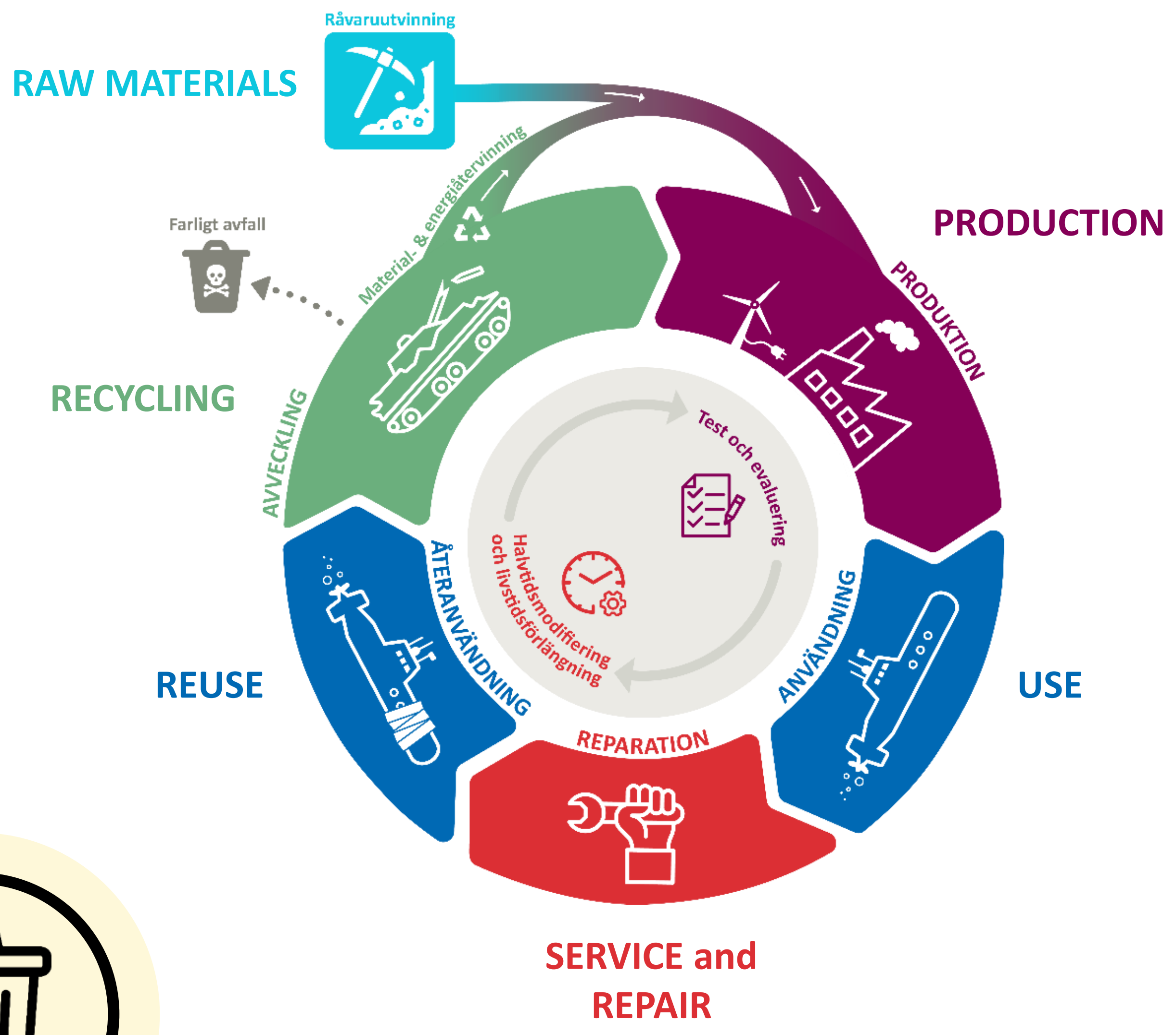
Requirements aiming to reduce greenhouse gas emissions

- Suppliers shall be certified according to ISO 14001 or fulfill equivalent environmental management system requirements
- Suppliers shall provide information on their activities which aims to:
  - reduce climate impact and energy consumption
  - prolong the lifetime of delivered products
- If possible provide LCA-data or Environmental Product Declarations
- Refrigerants shall have GWP-values below 150
- Equipment shall be compatible with fossil-free fuels

Circular economy

Promoting resource efficiency and circular economy perspectives by requiring:

- Control of critical raw materials supply
- Increased reuse of old components
- Use of renewable resources if possible
- Modular design to facilitate easy service/repair/replacement of components
- Flexible design to allow simple upgrades and product lifetime extensions
- Detailed recycling manuals in order to minimize waste and increase reuse



FMV

FÖRSVARETS MATERIELVERK

FMV

European Conference of Defence and the Environment

ECDE 2024

ROBERT SIPEC
Chief Nuclear Power Branch US Army

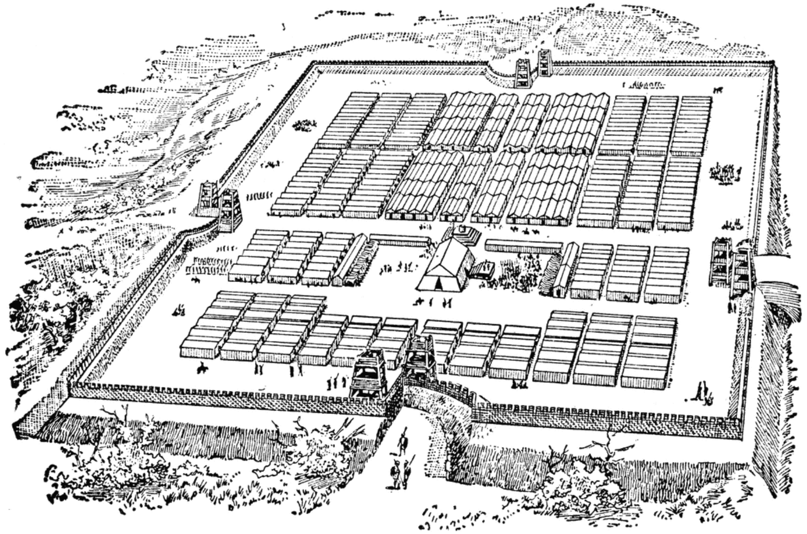
EUROPEAN
CONFERENCE OF
DEFENCE AND THE
ENVIRONMENT

Energy Requirements of the Future Deployable Military Camps from the MoDs' Perspective

Colonel
Robert Šipec
Logistics Directorate
Energy Efficiency and Green Transition Division

Existing Situation

Future Military Camp?



Impact on the Future Deployable Military camps

- all geographic regions and climate regions
- different conflict situations
- climate change-related threats
- requirements to reduce environmental / local impact
- requirements to reduce logistic burden
- multinational cooperation
- new / modified kinetic threats
- military mindset and behavioral change (RLS, MWA,...)
- ...

A European Green Deal

Striving to be the first climate-neutral continent

Council of the European Union

Brussels, 9 November 2020
(OR. en)

12741/20

COPS 389
CFSP/PESC 977
CSDP/PSDC 545
POLMIL 171
CLIMA 289
ENV 694
RELEX 870

COVER NOTE

From:	European External Action Service (EEAS)
To:	Delegations
Subject:	Climate Change and Defence Roadmap

Delegations will find attached document EEAS(2020)1251.

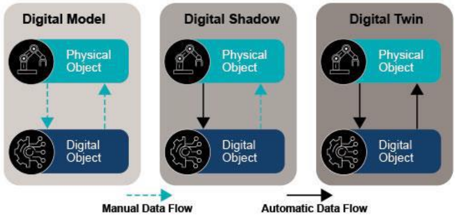
Encl.: EEAS(2020)1251

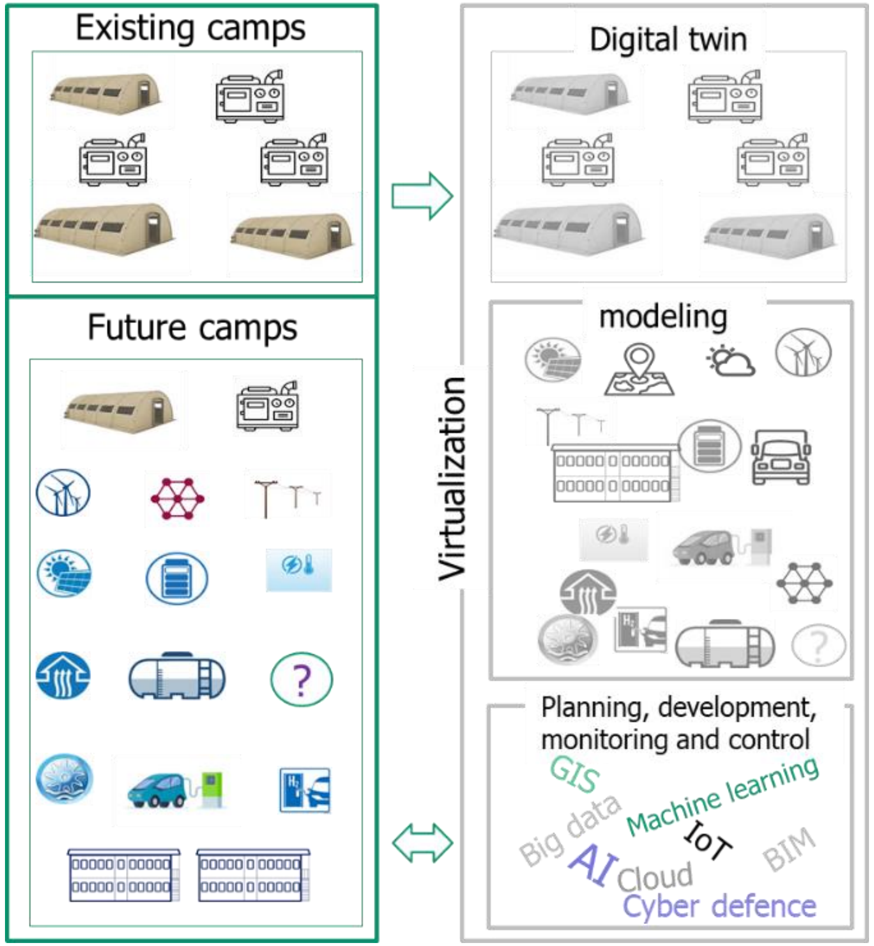
Impact on the Energy Requirements of the Future Deployable Military Camps

- increase of energy demand:
  - weapon systems (DEW,...)
  - multi UxV / exoskeletons
  - material handling equipment
  - surveillance
  - on site manufacturing / 3D printing
- increase of energy autonomy
- lower fossil fuel dependency
- on site energy production and storage
- growing share of renewables
- modularity

Impact on the Energy Requirements of the Future Deployable Military Camps

- multi fuel / multi energy / multi charging
- G2V; V2G; V2V
- Energy Management Systems:
  - advanced planning tools
  - multi layer / multi national
  - digital twin with advanced algorithms
  - Plug and Play functionality
- interoperability
- minimizing maintenance and supply chain
- Military / Civil
- low EM detectability
- low / zero GHG emissions





National and International Cooperation

EDA Energy and Environment Capability Technology Group

EnE CapTech

Energy Defence Consultation Forum

CF SEDSS

H2020 funded

Offshore Renewable Energy in Defence

SYMBIOSIS

Horizon Europe funded

Incubation Forum for Circular Economy in European Defence

IF CEED LIFE- LU

Si EnE | Slovensko partnerstvo za energijo in okolje na obrambnem področju

NATO
OTAN

EUROPEAN
CONFERENCE OF
DEFENCE AND THE
ENVIRONMENT

Thank you for your attention.

European Conference of Defence and the Environment

ECDE 2024

BERNARD THONON
CEA France

EUROPEAN
CONFERENCE OF
DEFENCE AND THE
ENVIRONMENT

INDY | Energy Independent Energy Efficient Deployable Military Camps

Funded by the European Union

ECDE 2024

DEFENCE, CLIMATE AND ENVIRONMENT – COINCIDING, NOT CONFLICTING POSSIBILITIES

Technologies and solutions for energy resilient and energy independent military camps

Bernard Thonon

cea

Funded by the European Union | Project No.: 101103388. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Commission. Neither the European Union nor the granting authority can be held responsible for them".

THE CONTEXT

- Energy Context
  - ➢ Vulnerability of the energy supply chain and infrastructures to climate change and political instabilities
  - ➢ High EU dependency on imported fossil fuel
- EU Strategy
  - ➢ Technology independency
  - ➢ Global energy strategy towards Net Zero GHG emissions in 2050 (EU-Green Deal and FIT for 55)
- Defence priorities
  - ➢ Critical infrastructure protection and energy security
  - ➢ Maintain the operational and tactical capacities
  - ➢ An expected growing demand of energy in the future operational environment
  - ➢ An integrated vision of energy including stationary and mobile systems for both operational and tactical levels

OBJECTIVE	2030	2050
FOSSIL FUEL for the camp & operations	40% reduction	100% reduction
Energy EFFICIENCY	20% primary energy saving	30% primary energy saving
ENERGY AUTONOMY of the camp	35%	70%
ENERGY AUTONOMY of the operations	10%	30%
FUEL LOGISTIC for the camp	35% reduction	70% reduction
FUEL LOGISTIC for operations	10% reduction	30% reduction

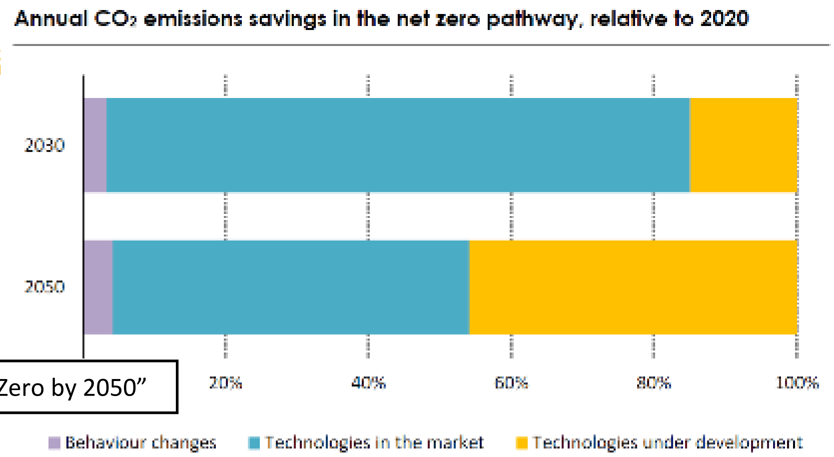
INDY Roadmap for EEMC

What are the specific needs of the EU defence sector in term of Energy Technologies and Solutions?

EDA statement: *"the total energy consumption of Member States' armed forces equals that of a smaller EU country"*

THE ROLE OF TECHNOLOGY IN ENERGY TRANSITION

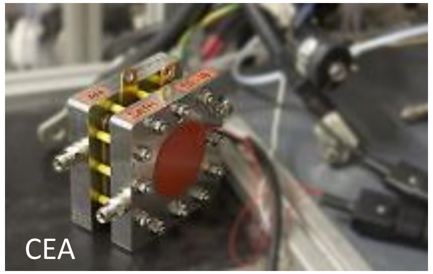
- 2030
  - 80% of the solutions are available in the market
  - 15% of the solutions are under development
- 2050
  - 50% of the solutions are available in the market

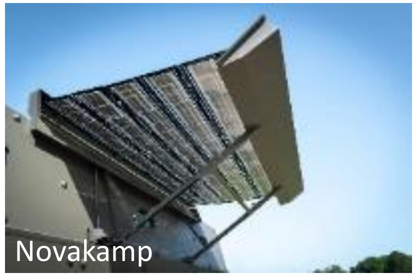


Ref. IEA, “Net Zero by 2050”

INDY:
- 70 emerging technologies evaluated
- Ranking with specific KPI (technical, economic and operational)

	Electricity	Heat/Cold	Fuel/Gas
Source			
Conversion			
Storage			
Distribution			


CEA

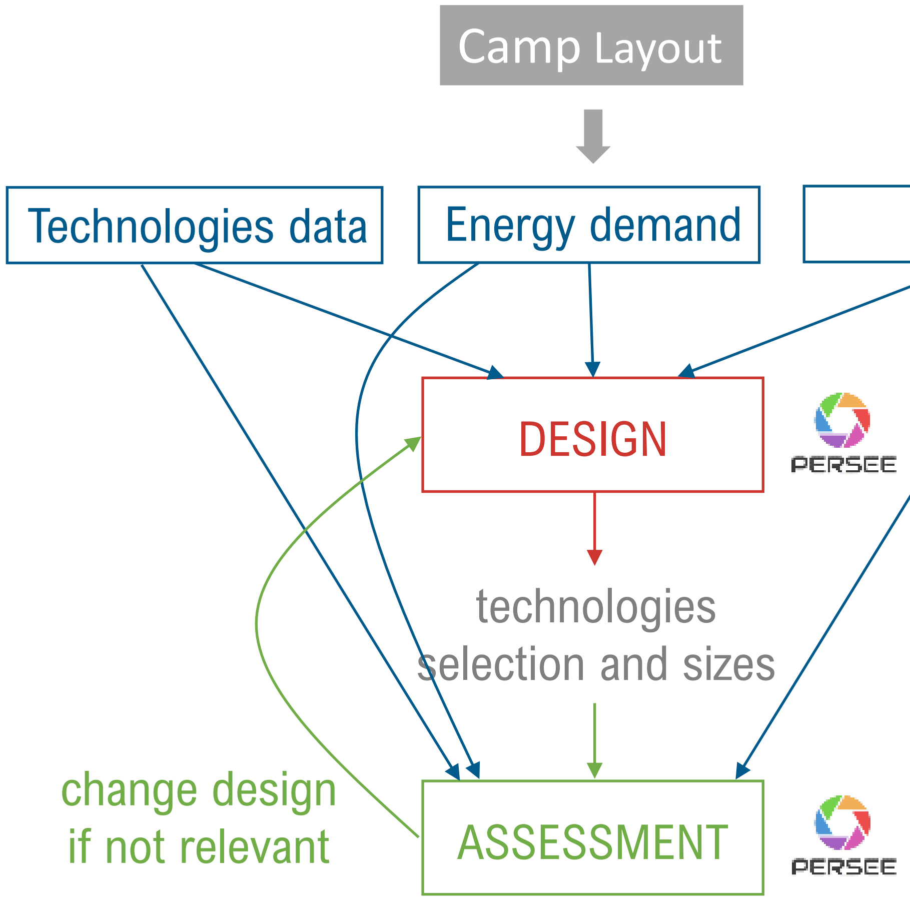

Novakamp


Intracom


IFE


Rheinmetall

TECHNOLOGY AND ARCHITECTURE DEFINITION METHODOLOGY



A single **generic model** for a case study that can be used with **different levels of details**

simple model for design

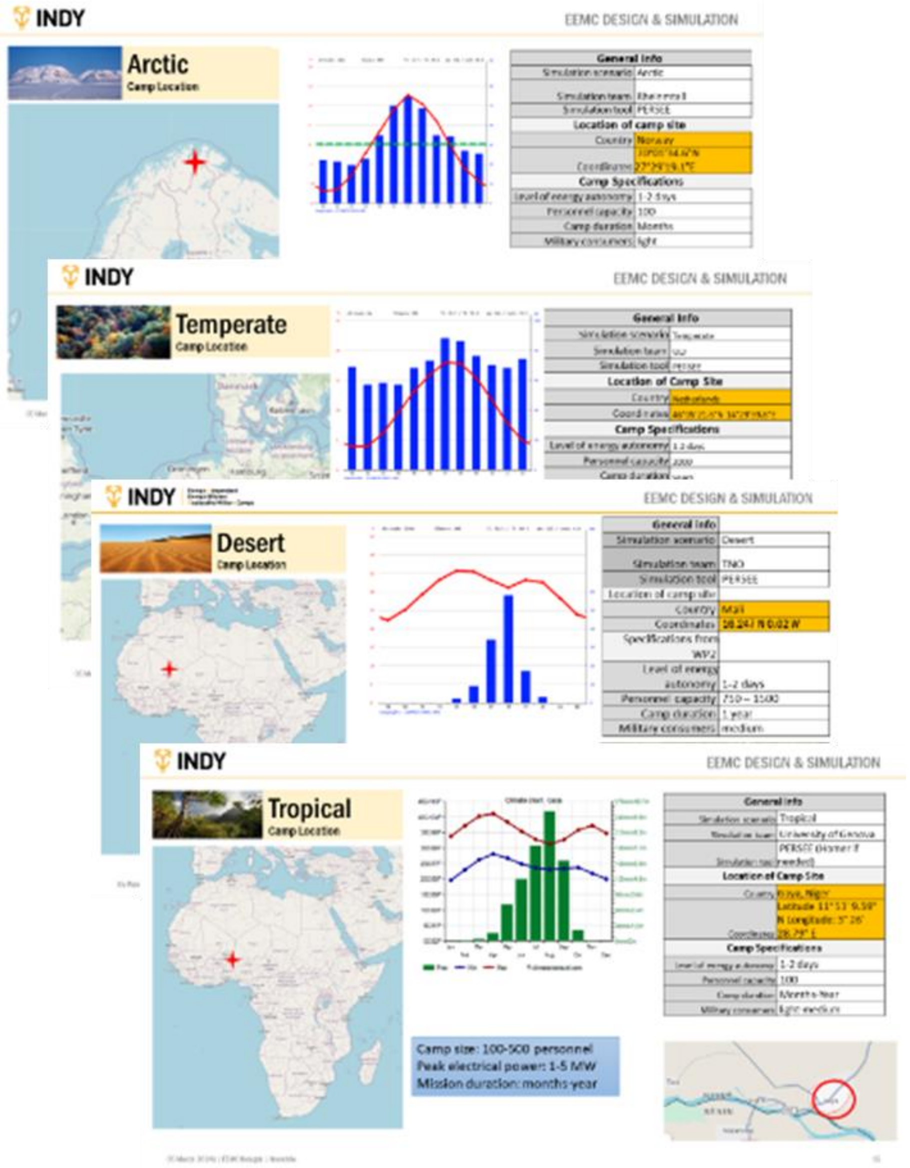
- optimized design and **coarse operation**
- single-step optimization under **perfect foresight**
- deterministic
- annual targets

more detailed model for assessment

- fixed design and **more realistic operation**
- rolling horizon optimization under **myopic foresight**
- deterministic or Monte-Carlo
- load shedding

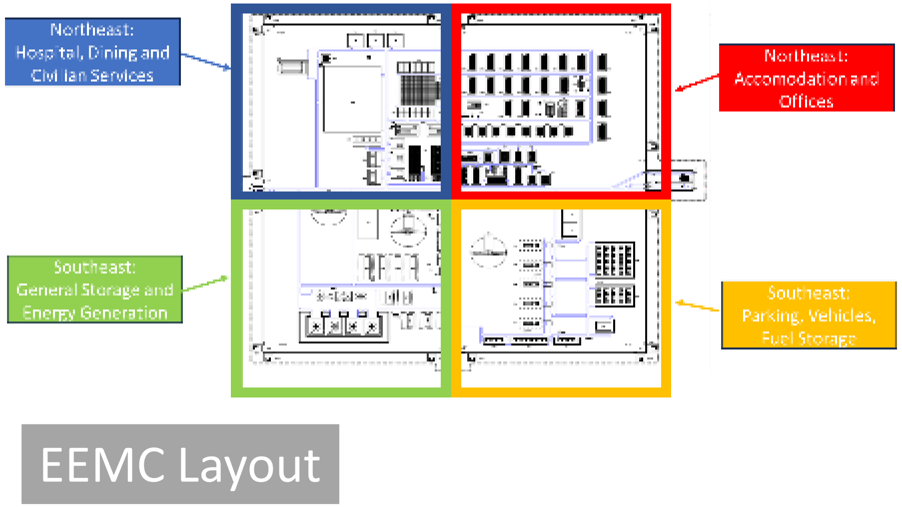
THE DEFINITION OF CASE STUDIES

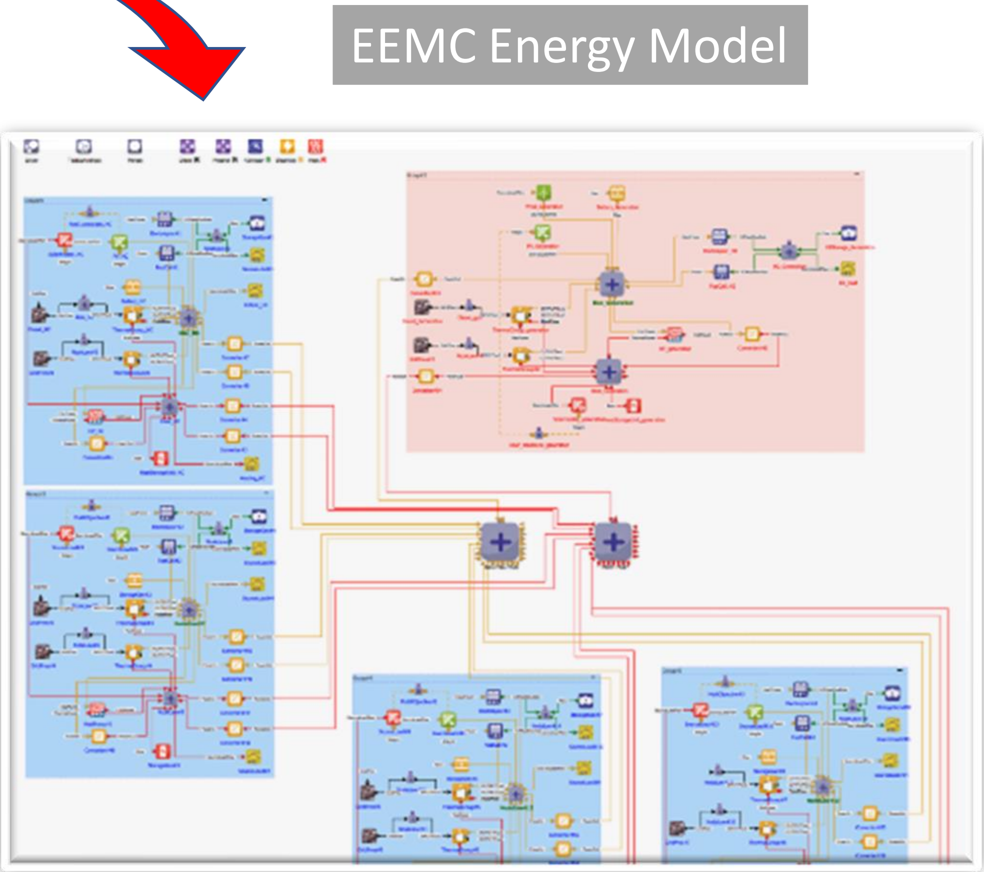
Scenario	
	**Arctic**
	**Temperate**
	**Desert**
	**Tropical**

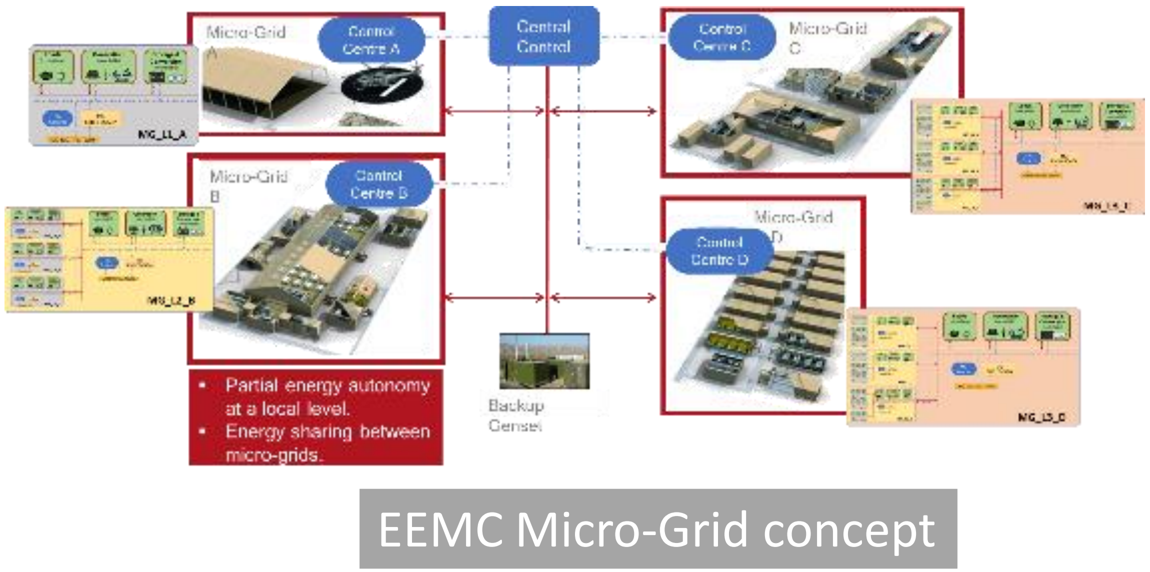


Climate	Personal capacity			Electrical power			Camp duration			Mil. consumers		
	100	1000	2000	100 kW	5 MW	20 MW	mths	year	years	light	med	heavy
Arctic	X			X			X			X		
Temperate*			X			X			X			X
Desert		X			X			X			X	
Tropical*	X			X			X			X		

CAMP LAYOUT AND ENERGY ARCHITECTURE







WHICH ENERGY SYSTEM COMPONENTS WILL BE USED?

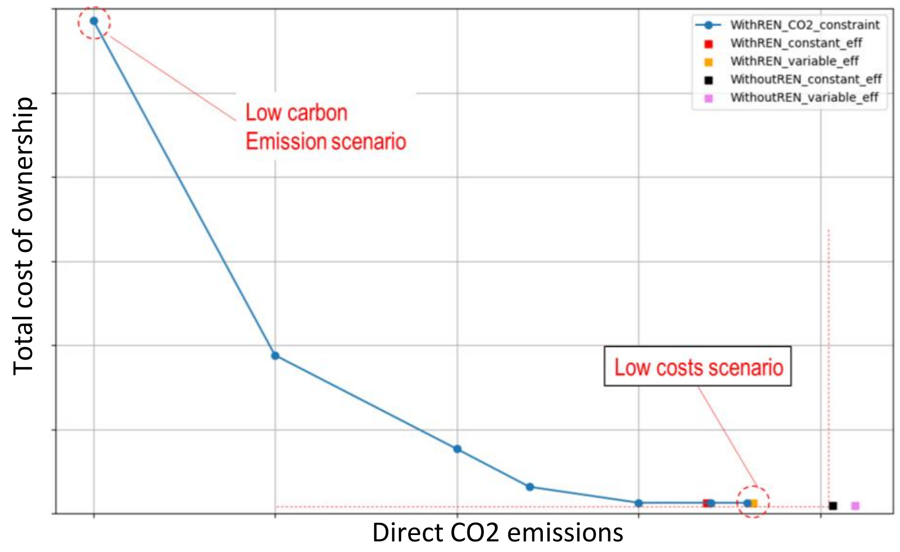
EXPERT HIGH LEVEL SELECTION

- Electricity generation
- Heat generation
- Hydrogen and syngas
- Liquid fuel
- Waste to energy

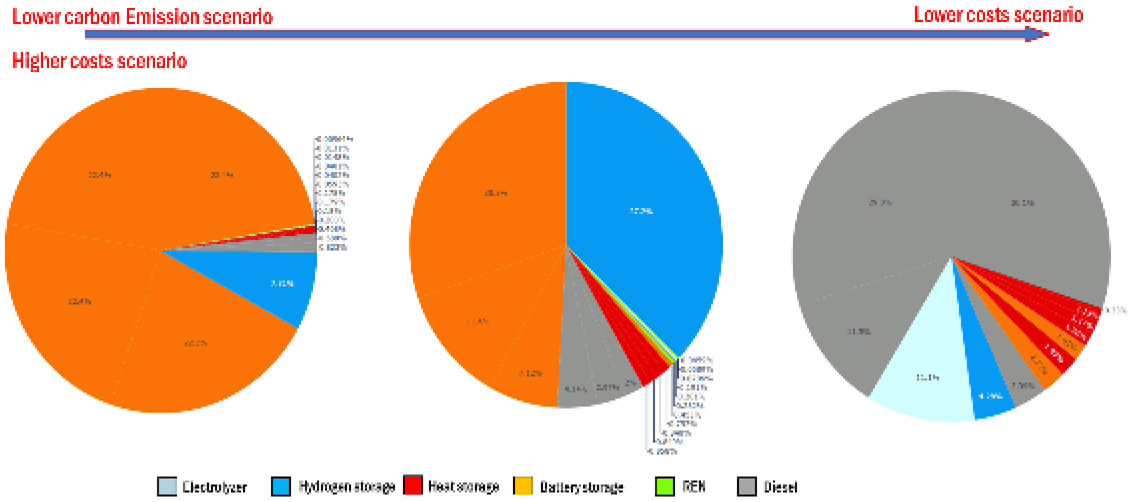
Electricity Sources, Storage & Conversion	Temperate	Tropical	Desert	Arctic
Grid	No	No	No	No
Photovoltaics	Yes	Yes	Yes	Yes
Wind Turbine	Yes	Yes	Yes	Yes
Batteries	Yes	Yes	Yes	Yes
Genset 1 (Diesel to Electricity)	Yes	Yes	Yes	Yes
Genset 2 (Methanol/ CH_4 to Electricity)	Yes	Yes	No	No
Fuel Cell 1 (Hydrogen to Electricity)	Yes	Yes	Yes	Yes
Fuel Cell 2 (Methanol/CH_4 to Electricity)	No	No	Yes	No

Waste Conversion	Temperate	Tropical	Desert	Arctic
Waste to Heat	Yes	No	No	No
Waste to Methanol	Yes	No	No	No
Methanation from Waste	Yes	No	No	No

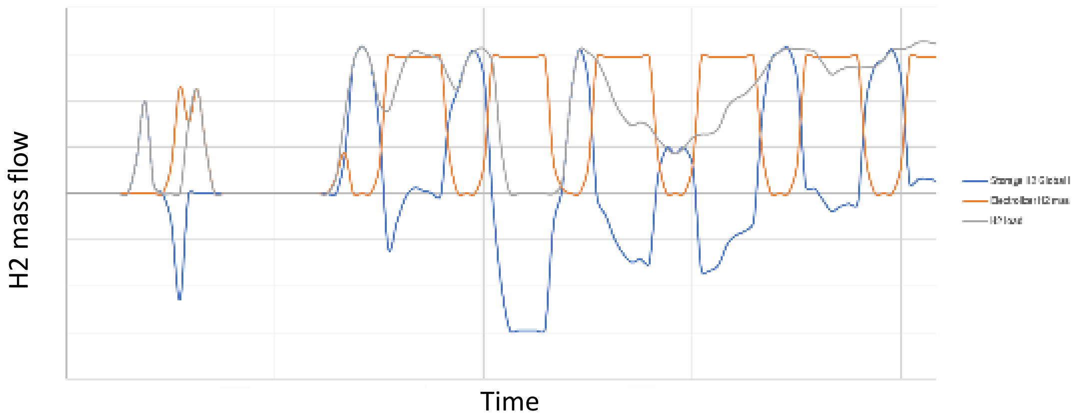
EXAMPLE OF RESULTS



Evolution of the Cost of Ownership in function of the CO2 content



Technology definition in function of the scenario



State of charge of hydrogen storage and electrolyser

Results:

- Production commitment to demand load
- Production, storage and conversion optimal sizing and operation
- Performance and Cost breakdown
- Sensitivity & Uncertainty analysis

TECHNOLOGIES AND INNOVATION PROCESS

- Dual Usage Energy Technologies
  - Civil driven energy technology innovation
  - Promote collaborations between civil and defence sector (spin-in concept)
  - Technology and knowledge transfer
  - Adapt technologies to defence requirements
  - Develop specific integration solutions
  - Interoperable solutions
- Demonstrate the reliability in defence environment
  - Characterise technology performances in representative environment
  - Integrate solutions at system level and qualify in real military environment

THE DIGITALISATION OF ENERGY INFRASTRUCTURES

- Design and evaluation of component and systems
  - Numerical representation of the physical system
  - Hardware in the loop approach (semi virtual representation)
- Plan and optimise operation
  - Forecast the usage
  - Evaluate energy architecture
  - Select component and optimal control
- Exploit and maintain in operative conditions
  - Connection to the real system
  - Real time simulation
  - Detect defaults

INDRA-Thales

Leonardo

INDY | Energy Independent Energy Efficient Deployable Military Camps

Thank you!

Funded by the European Union

Funded by the European Union | Project No.: 101103388. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Commission. Neither the European Union nor the granting authority can be held responsible for them.

European Conference of Defence and the Environment

ECDE 2024

ANN MARIE KAMMERER
Nuclear Power Branch US Army

EUROPEAN
CONFERENCE OF
DEFENCE AND THE
ENVIRONMENT

Benefits and Opportunities of Transportable Microreactors and their Potential Role in Mission Assurance

June 2024

European Conference of Defence and the Environment: *Defence, climate and environment: Coinciding, not conflicting possibilities*
Oslo, Norway

Office of the Chief of Engineers
Nuclear Power Branch

If you could have…

- the power needed to ensure your mission,
- produced at the point of need,
- with no logistics tail,
- not just for today's missions but tomorrow's as well,

What would you do? What systems could you imagine?

What if you could have…

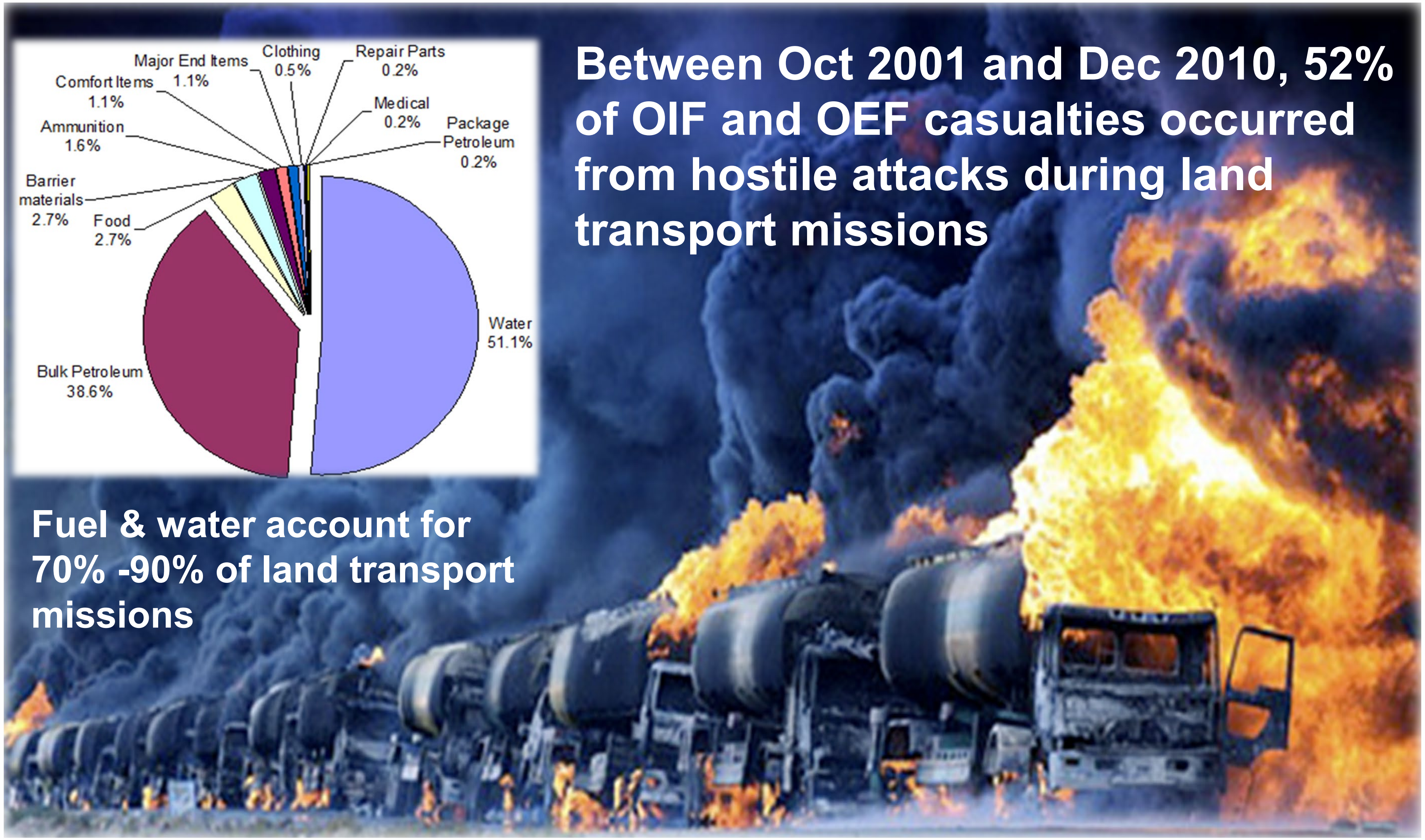
- Not just electricity, but also heat, and the ability to produce synthetic (carbon-recycled) liquid fuels such as JP8, JET-A, and Diesel produced at the point of need?

What would you do? How much of an impact could this have? The US DOD is working towards that future with projects such as Project Pele (transportable microreactor) and SynCE (synthetic fuel)

Potential Impacts of Transportable Microreactors

- Increased mission assurance, particularly in contested and austere environments
- Reduced carbon emissions – both from generator use and the fuel used in the logistics tail
- Reduced loss of life associated with “liquid logistics”

Catalyst for Reevaluating Energy Options



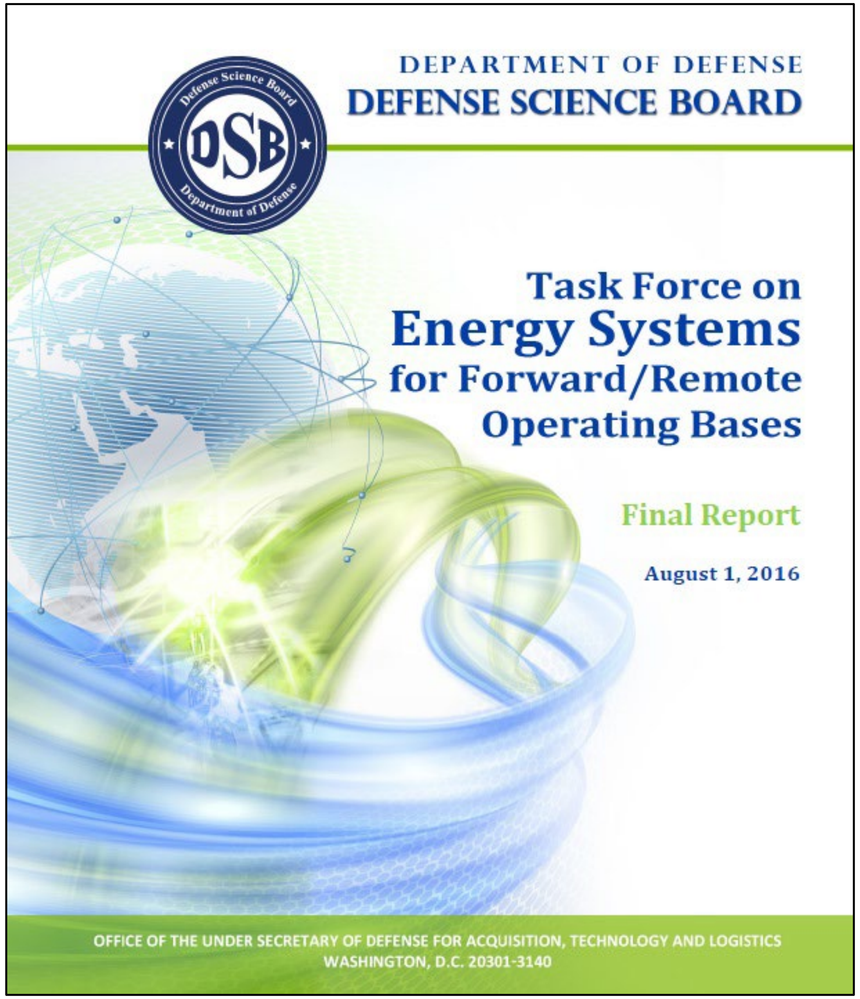
Between Oct 2001 and Dec 2010, 52% of OIF and OEF casualties occurred from hostile attacks during land transport missions

Fuel & water account for 70% -90% of land transport missions

"Relieve the dependence of deployed forces on vulnerable fuel supply chains"
Commanding General, 1st Marine Division in OIF

Evaluation of Energy Options

In 2016 the Defense Science Board (DSB) identified **energy as a critical enabler of future military operations**. The study noted that battlefield energy usage will likely increase significantly over the next few decades with energy needs of current and **future military capabilities and operations likely outpacing improvements to energy efficiency and management**. The DSB found that **intermittent character of many alternative energy sources do not appear able to keep pace with the growth of the DoD's energy needs**, concluding that, **"the U.S. military could become the beneficiaries of reliable, abundant, and continuous energy through the deployment of nuclear energy power systems"**.



The study also noted the significant technological advances in nuclear power since the 1960s.

What is Project Pele

- Project Pele is a prototype project of the US DOD Strategic Capabilities Office (SCO).
- “The project's objective is to design, build, and demonstrate a prototype mobile nuclear reactor within five years, following the DSB study recommendations. This effort will leverage state-of-the-art technologies and recent advances in nuclear engineering to deliver an inherently safe nuclear reactor. The reactor will be designed to provide reliable and resilient power, while minimizing risk of nuclear proliferation, environmental damage, or harm to nearby personnel or populations.”

https://www.cto.mil/pele_eis/

“Significant technological advances in nuclear power since the 1960s”

An Air Force telephone from 1957

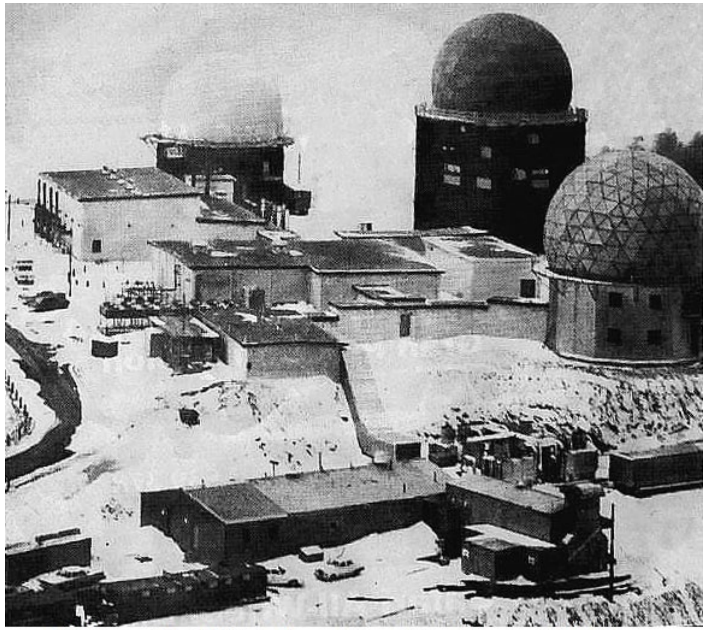
The first U.S. nuclear reactor to be connected to an electrical grid, in 1957, was a US Army reactor (SM-1)

Portable Nuclear Power: An Old Idea

- The U.S. Army Nuclear Power Program ran from 1954 through 1977.
  - Eight reactors were constructed (five were portable), each between 1-10 MWe, of various designs and for various purposes.

- The first U.S. nuclear reactor to be connected to an electrical grid, in 1957, was an Army reactor (SM-1).

- As some of the earliest nuclear reactors ever built, they were technologically difficult to operate, unreliable, and too expensive relative to abundant fossil fuel alternatives.



PM-1 Nuclear Plant (PWR), Sundance Air Force Station, Wyoming, 1962-1968

ML-1 US Army reactor, 1958, Arco, Idaho

Floating Nuclear Power: The MH-1A *Sturgis*

The MH-1A, or Mobile High Power Reactor Number 1A, was the Army's first floating nuclear power plant and the last reactor created under the Army Nuclear Power Program. The Army wanted MH-1A to supply electric power in situations where it was not feasible to rely on conventional power generation methods—during war or natural disasters, for example. The Army envisioned using a highly mobile, large-scale power generator for short-term missions and emergencies where conventional fuel might not be available.

To carry the MH-1A, the Corps of Engineers retrofitted a surplus World War II Liberty cargo ship, the *Charles H. Cugle*, to become a nuclear power barge. They renamed it the *Sturgis*, in honor of Lt. Gen. Samuel Sturgis, who was Chief of Engineers during the formative years of the Army Nuclear Power Program. By July 1964, the Alabama Dry Dock and Shipbuilding Company had removed the ship's engines, inserted a new midsection, and installed the reactor containment structure. After the finishing touches in Mobile, Alabama, the *Sturgis* was towed to Fort Belvoir for the loading of the reactor core and final testing. The plant began operating on January 25, 1967.

The first assignment for the MH-1A *Sturgis* came quickly. A drought had caused a shortage of hydroelectric power in Panama, so in July 1968 the Army sent the nuclear power barge to Gatun Lake at the Panama Canal where it provided power essential for canal operations until 1976.

That year the Army deemed the cost of maintenance and upgrades to the power plant unjustifiable, and it placed the *Sturgis*—its reactor removed—into the James River Reserve Fleet. In 2015 the *Sturgis* was towed to Galveston, Texas, where crews began to decommission the reactor and dismantle the vessel.

Technicians prepare the last fuel rod assembly for transport to MH-1A prior to its startup, March 1965.

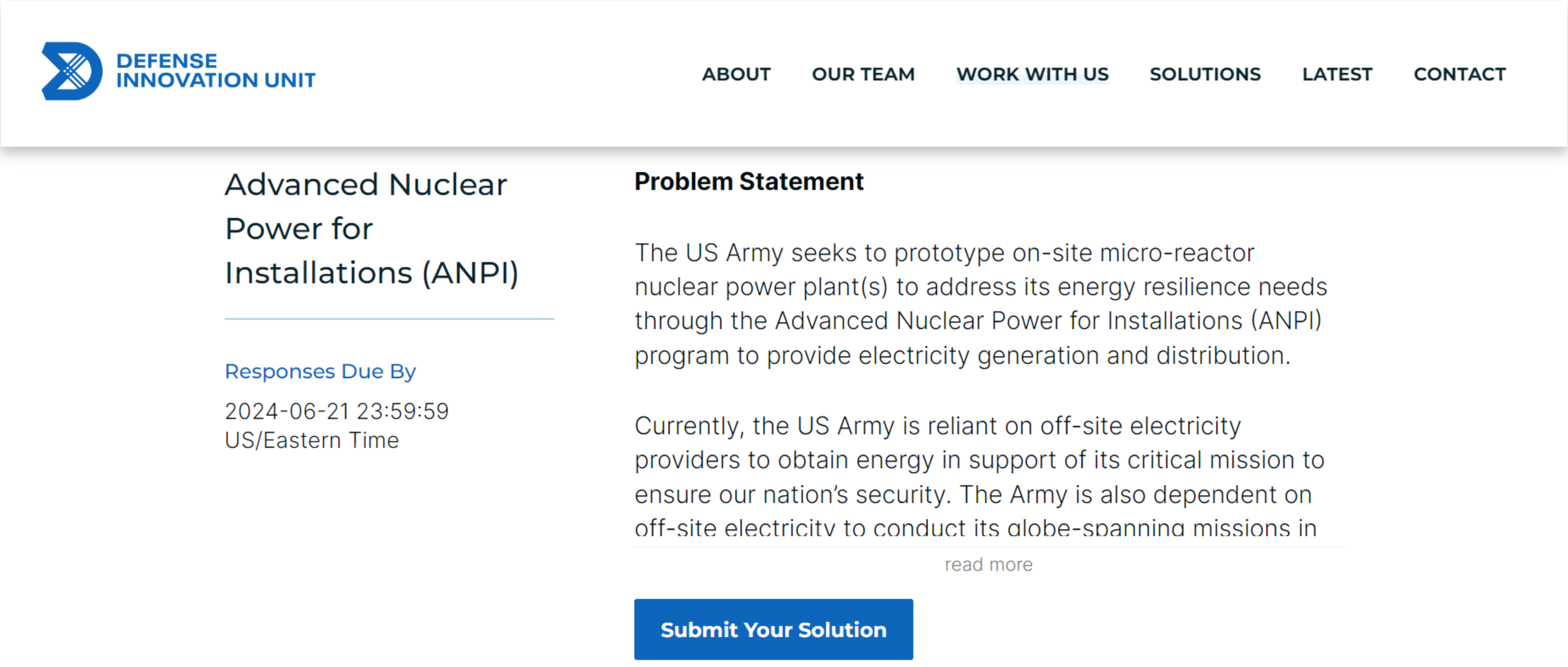
The control room on the MH-1A *Sturgis* while in service at the Panama Canal.

The MH-1A *Sturgis* producing electrical power for the Panama Canal.

https://www.usace.army.mil/About/History/Exhibits/Nuclear-Power-Program/Sturgis/

FAQ: What is a microreactor?

- A microreactor is defined as a nuclear fission reactor that produces approximately 50 megawatts of electrical energy or less.
- A Small modular reactor is generally defined as a reactor between 50 and 300 megawatts electric
- US DOD projects targeting 1-5 MWe for transportable reactors and 3-10 MWe for stationary reactors
  - "SUPPLEMENTAL INFORMATION REPORT PROJECT PELE » https://www.cto.mil/wp-content/uploads/2023/10/Pele_SIR_CITRC_Pad_A-PW_DistA.pdf
  - https://www.diu.mil/work-with-us/open-solicitations (only available through

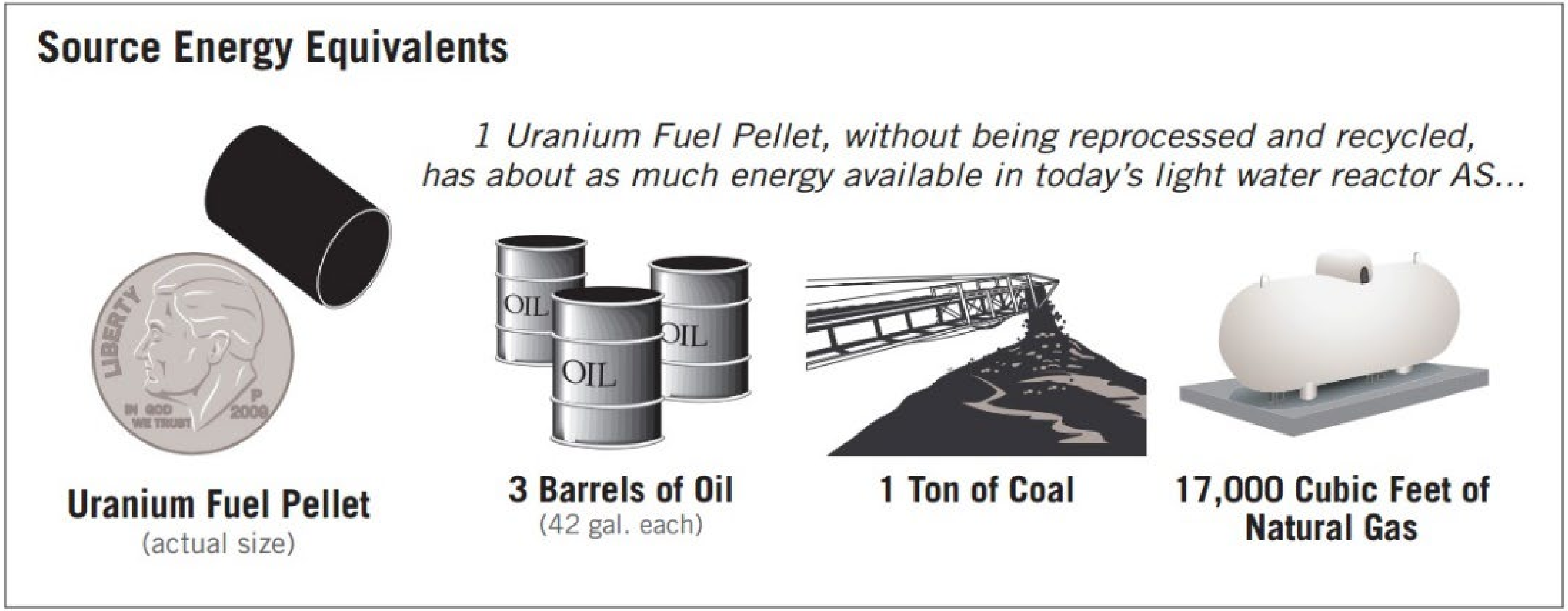


- https://www.diu.mil/work-with-us/open-solicitations

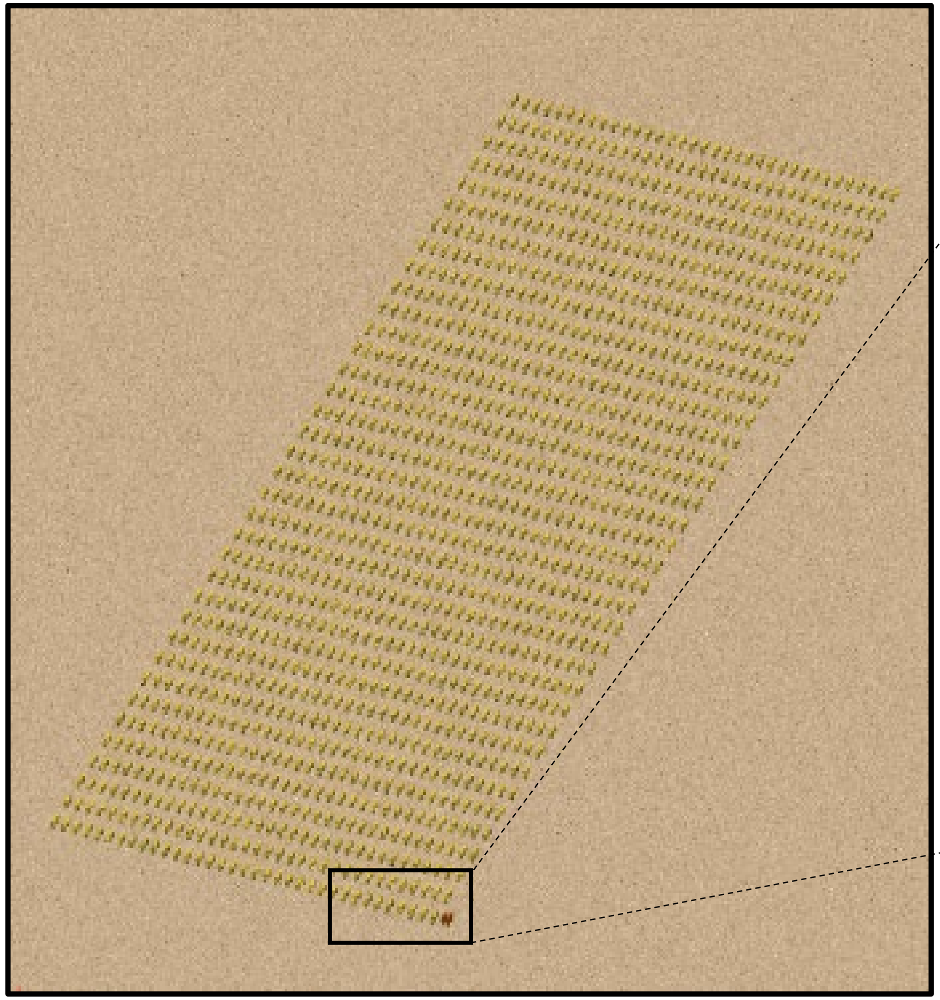
FAQ: Why is Nuclear Power so Different?

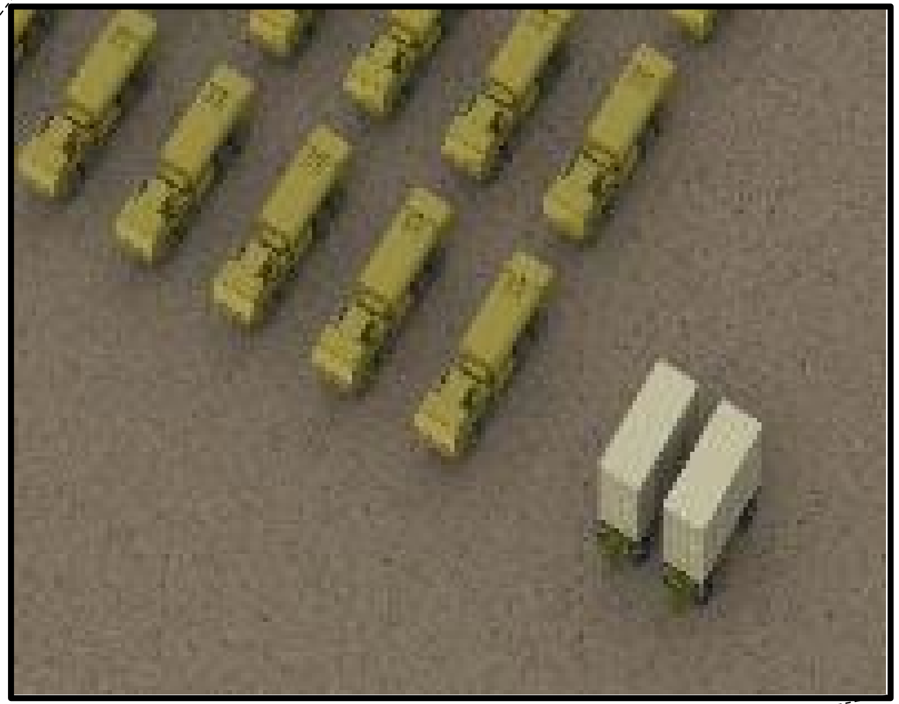
Energy Density and Nuclear Power

Uranium-235 is *two million* times as energy dense as diesel



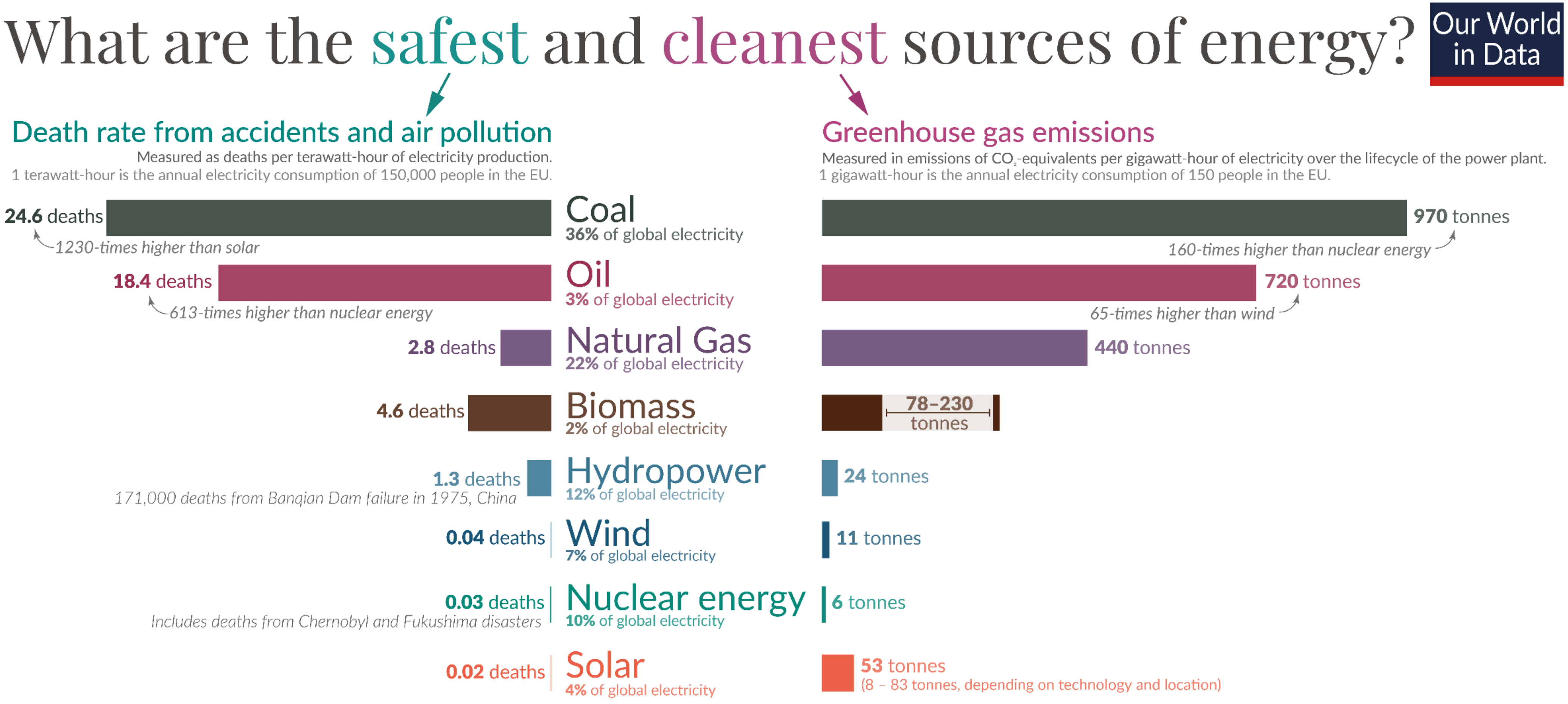
Nuclear Power Is a Logistical and Environmental Game Changer





- Fuel trucks required to produce 1.5MWe for 3 years with 2 MEP-810 generators.
- Figure does not include fuel required for logistics
- MEP-PU-810 generator, rated for 840 kW output, consumes 60 gallons (180 kg) of JP-8 per hour

FAQs:
Is it safe?
What about the spent fuel/waste?



Death rates from fossil fuels and biomass are based on state-of-the art plants with pollution controls in Europe, and are based on older models of the impacts of air pollution on health. This means these death rates are likely to be very conservative. For further discussion, see our article: OurWorldinData.org/safest-sources-of-energy. Electricity shares are given for 2021.

Data sources: Markandya & Wilkinson (2007); UNSCEAR (2008; 2018); Sovacool et al. (2016); IPCC AR5 (2014); UNECE (2022); Ember Energy (2021).

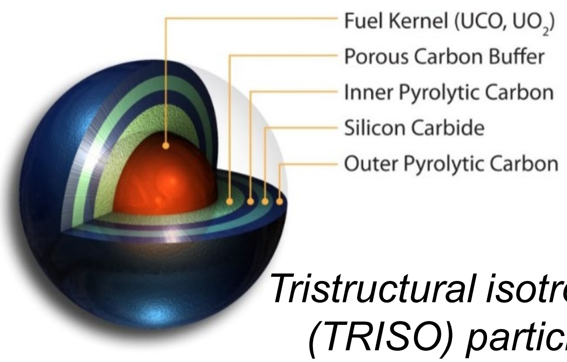
OurWorldinData.org – Research and data to make progress against the world's largest problems.

Advanced microreactors are inherently safe

- Passively safe (i.e., they do not require operator intervention or powered systems to remain in a safe condition following shutdown)
- Use advanced fuel forms with high-assay low enriched uranium (HALEU/U-235 enriched to less than 20%)
- Use recirculating coolant fluids (gas, liquid metals, etc.) with passive convection
- Do not require large containment buildings

TRISO Fuel

- **The Advanced Gas Reactor (AGR) Fuel Development Program was initiated in 2002**
  - TRISO fuel has already been subjected to rigorous testing by DoE, eliminating the need for DOD/SCO to develop or qualify a new fuel
- **Silicon carbide keeps fission products sealed inside, meaning that a containment vessel failure is no longer catastrophic**
  - Design reduces diversion and proliferation risks due to low (< 20% U235) enrichment and individually coated particles
  - Rugged, robust fuel structure deters use as an improvised weapon such as a dirty bomb
- **Innovative design using fuel form itself as first line of containment is a paradigm shift in safety for nuclear power**
  - TRISO fuel and compacts could significantly lower safety/O&M/regulatory costs
  - Pellets minimize consequences to the environment and population from events affecting integrity of reactor or threatening release of contamination



Tristructural isotropic (TRISO) particle

Cylindrical fuel compacts

Courtesy of OSD SCO, May 2024 Project Pele Update. Distribution Statement A

FAQ: What if it gets hit by a missile or explosive?

- The TRISO compacts are resistant to physical injury
- The reactor has a far smaller footprint than both the tank farms on base and the fuel convoys needed for generator power
- The reactor is located within a radiation shield structure that provides significant protection
- The DOD is currently funding high-velocity modeling and physical testing to better understand the potential impact of attack and to support emergency response planning

FAQ: Can a nuclear plant explode like a nuclear weapon?

It is impossible for a reactor to explode like a nuclear weapon; these weapons contain very special materials in very particular configurations, neither of which are present in a nuclear reactor.

- https://www.anl.gov/article/10-myths-about-nuclear-energy

FAQ: What about the spent fuel/waste?

- All of the used nuclear fuel generated in every nuclear plant in the past 50 years would fill a football field to a depth of less than 10 yards, and 96 % of this "waste" can be recycled. Used fuel is currently being safely stored
  - *K.S. Krane, Introductory Nuclear Physics, John Wiley and Sons, 1988*
- Nuclear energy is a clean energy source that can account for all of its byproducts, unlike other energy sources like fossil fuels.
- Used fuel is being safely shipped by truck, rail, and cargo ship today. To date, thousands of shipments have been transported with no leaks or cracks of the specially-designed casks.
  - *US Nuclear Regulatory Commission, "Backgrounder on Transportation of Spent Fuel and Radioactive Materials" https://www.nrc.gov/reading-rm/doc-collections/fact-sheets/transport-spenfuel-radiomats-bg.html*

Worth a read if you want a deep dive into nuclear waste

- The Boring Truth about Nuclear Waste

https://thebreakthrough.org/issues/energy/the-boring-truth-about-nuclear-waste?gad_source=1&gclid=CjwKCAjw65-zBhBkEiwAjrqRMGGwCCn_O74eRAwcZrdQNA40JuyyRFuh6fRDTrHnNaeoq_PZfJg1hxoCutsQAvD_BwE

Thank you for your kind attention