

WP1: scenarios leading to radiological consequences

Olena Pareniuk, Anastasiia Torianik, Volodymyr Borisenko, Mykola Talerko, Kateryna Shavanova, Yuliia Ruban, Serhii Paskevych

Risk matrix exercise:





**SSTC
NRS**

State Scientific and Technical Center
for Nuclear and Radiation Safety

Gennadiy Chumak

Researcher, Uranium Facilities Safety Laboratory,
Emergency Preparedness and Radiation Monitoring Department



RRADEW Consortium Workshop
24 - 25 March 2025, Lisbon, Portugal



Co-funded by
the European Union

Scope of work

This WP will **assess and evaluate the most likely scenarios for the deployment of hostilities at nuclear facilities.**

Evaluation of impact of factors of war or natural disaster will be conducted with focus on the individual dosimetric monitoring aspects of emergency response plans with respect to experience of Chernobyl, Fukushima, and war in Ukraine.

Based on existing sources and protocols, WP1 will assess vulnerabilities of facilities, in terms of both mechanical and technical aspects, as well as personnel vulnerability. For selected scenarios an evaluation of nuclear safety and security, as well as modelling the potential radioactive contamination will be carried out. Results will be used to produce a matrix-based assessment of potential risks to facilities, based on scenario, likelihood, and potential consequences. The scenarios and matrix will be evaluated together with expert stakeholders consisting of national decision-makers, facility operators, RP specialists, military experts, and other first line responders.

Criteria in the risk matrix.

Types of nuclear facilities	NPP that continues to generate	NPP is in cold shutdown	A repository for spent nuclear fuel	Lost source of ionizing radiation
The location of the nuclear facilities	Out of reach of the means of destruction due to the depth of the location	Far from the front line, but within the reach of air weapons	Within 50 km of the front line	Directly on the front line
Type of interaction with military operations	Hybrid military operations with an cyberattack on the Information and Computing System	Events that may occur during the movement of the front line past the territory of the nuclear facility	Shelling the object with means of long-range damage	Taking a nuclear facility and its personnel hostage
Cooling of reactors and spent fuel pools	Artificial reservoir	Natural reservoir (river, sea, etc)	Supply from wells	N/A
Protection measures for civilians	Does not require the evacuation of the civilian population	Civilian notification and evacuation measures have been developed	Measures to notify civilians by the Ukrainian authorities are complicated	Evacuation of the civilian population is impossible
Isotopic composition of the emission				

Qualitative risk matrix outcomes

Possible combinations of factors					Types of impacts						Sum	Significance
					Social	Economic	Political-informational	Health	Educational and scientific	Environmental		
NPP that continues to generate	Out of reach of the means of destruction due to the depth of the location	Hybrid military operations with an cyberattack on the Information and Computing System	Artificial or natural reservoir	Does not require the evacuation of the civilian population		2	3	5	2	3	2	17 4 Likely
				Civilian notification and evacuation measures have been developed		3	3	5	3	3	2	19 4 Likely
				Measures to notify civilians by the authorities are complicated		4	4	5	4	3	2	22 4 Likely
		Shelling the object with means of long-range damage	Artificial or natural reservoir	Does not require the evacuation of the civilian population		3	3	5	3	3	3	20 3 Moderate
				Civilian notification and evacuation measures have been developed		4	3	5	4	3	3	22 3 Moderate
				Measures to notify civilians by the authorities are complicated		5	3	5	5	3	3	24 3 Moderate
	Far from the front line, but within the reach of air weapons	Shelling the object with means of long-range damage	Artificial or natural reservoir	Does not require the evacuation of the civilian population		3	3	5	2	3	3	19 4 Likely
				Civilian notification and evacuation measures have been developed		3	3	5	2	3	3	19 4 Likely
				Measures to notify civilians by the authorities are complicated		3	3	5	3	3	3	20 4 Likely
		Hybrid military operations with an cyberattack on the Information and Computing System	Artificial or natural reservoir	Civilian notification and evacuation measures have been developed		3	4	5	2	3	4	21 5 Almost Certain
				Measures to notify civilians by the authorities are complicated		3	4	5	3	3	4	22 5 Almost Certain
				Civilian notification and evacuation measures have been developed		4	5	5	4	3	4	25 4 Likely
NPP is in cold shutdown	Out of reach of the means of destruction due to the depth of the location	Hybrid military operations with an cyberattack on the Information and Computing System	Artificial or natural reservoir	Does not require the evacuation of the civilian population		3	3	3	2	2	2	15 5 Almost Certain
				Civilian notification and evacuation measures have been developed		3	3	3	2	2	2	15 5 Almost Certain
				Measures to notify civilians by the authorities are complicated		3	3	3	2	2	2	15 5 Almost Certain
		Shelling the object with means of long-range damage	Artificial or natural reservoir	Does not require the evacuation of the civilian population		4	3	3	2	2	2	16 4 Likely
				Civilian notification and evacuation measures have been developed		3	3	3	2	2	2	15 4 Likely
				Measures to notify civilians by the authorities are complicated		4	3	3	2	2	2	16 4 Likely
	Within 50 km of the front line	Hybrid military operations with an cyberattack on the Information and Computing System	Artificial or natural reservoir	Does not require the evacuation of the civilian population		3	3	4	3	3	3	19 3 Moderate
				Civilian notification and evacuation measures have been developed		3	3	4	3	3	3	19 3 Moderate
				Measures to notify civilians by the authorities are complicated		3	3	4	3	3	3	19 3 Moderate
		Shelling the object with means of long-range damage	Artificial or natural reservoir	Does not require the evacuation of the civilian population		3	3	4	3	3	3	19 3 Moderate
				Civilian notification and evacuation measures have been developed		3	3	4	3	3	3	19 3 Moderate
				Measures to notify civilians by the authorities are complicated		3	3	4	3	3	3	19 3 Moderate

Identified: **68 scénarios**

Low impact: **2 scénarios**

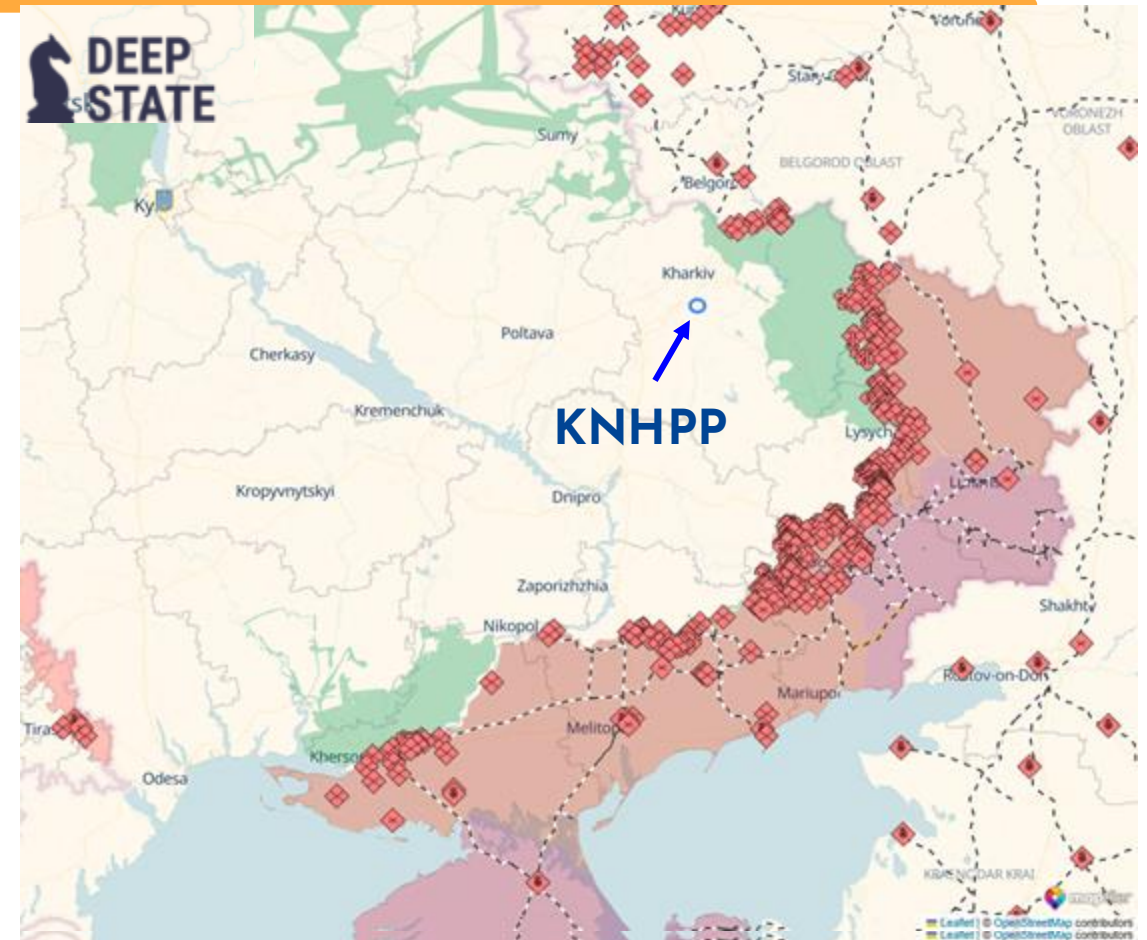
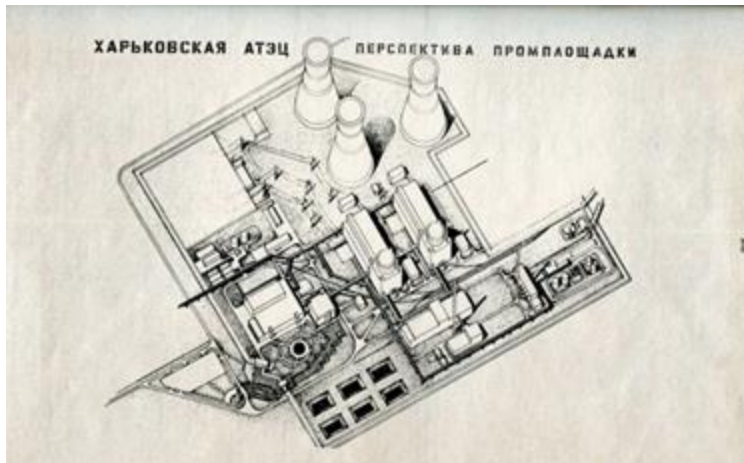
Moderate impact: **44 scénarios**

High impact: **22 scénarios**

Location of the mock NPP

Kharkiv Nuclear Heating and Power Plant

- 2 units of VVER-1000
- has spent fuel pools
- construction stopped in 1990
- nearest city - Kharkiv,
population (2021) - 1 455 029
population (2025) - 1 195 670



General characteristics

NPP characteristics:

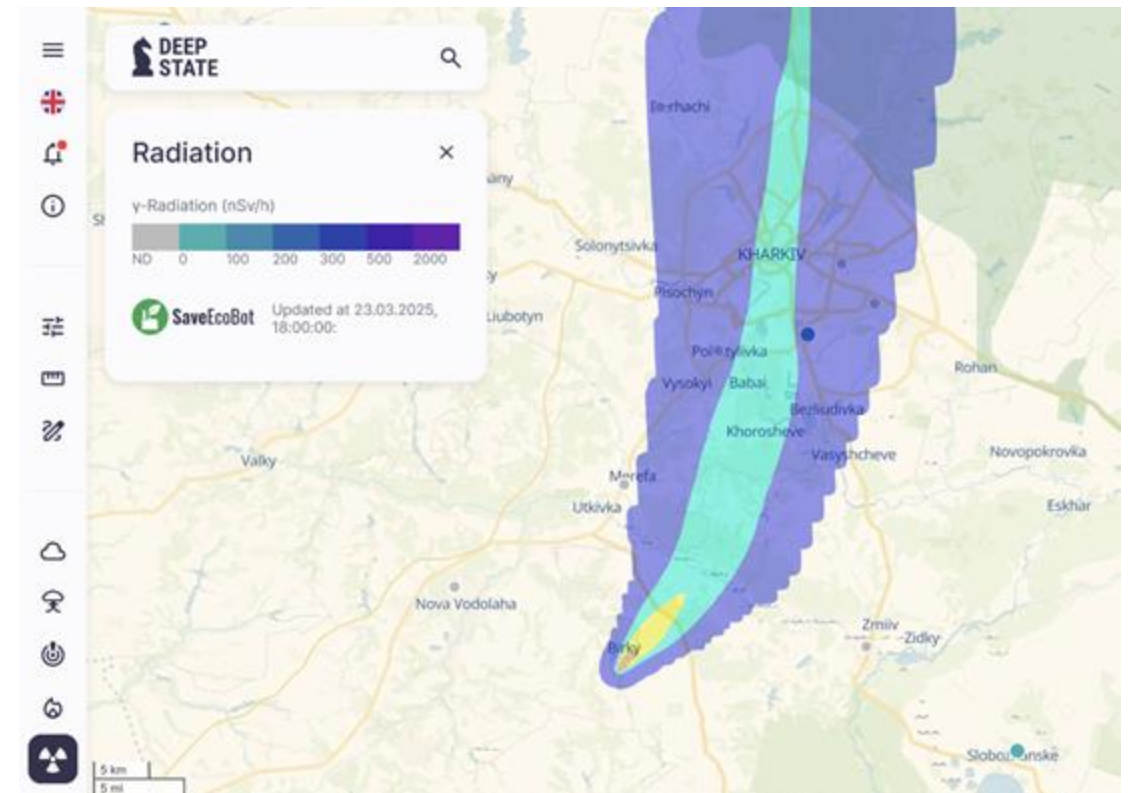
Fuel assemblies A -4.4%, U235
operated for 4 fuel loads (1320 ef. days),
burnup 60,645 MW*d/t U

Response characteristics - personnel:

SESU personnel - 583 (27 teams)
SSTS - 752 (16 teams)

MoD - 174 (4 teams)

Exposure monitoring posts



Scenario 1: Missile attack on a generating NPP

Missile attack on a generating NPP. Consequences of a hit to the protective containment of a power unit. Consequences of a hit to the circulation pumps.

According to the matrix:

- generating NPP
- far from the front line, but within the range of air weapons
- shelling of the facility by long-range weapons
- 100% of the power grid is working
- measures to alert the civilian population are complicated

GRIT: Ground Rehabilitation through Innovation Technologies

The screenshot displays the GRIT web application interface. At the top left is the GRIT logo, and at the top right are logos for Demine Ukraine and the Ministry of Communities and Territories Development of Ukraine, along with a note about partnership with the EU. The main heading is "Welcome to GRIT!". Below this, there are six tool cards arranged in a 2x3 grid:

- Automated Prioritization Homepage:** Multi-criteria prioritization of land plots. The card shows a map of Ukraine with a highlighted region.
- Executive Dashboard:** Country-level impact analysis and mine action. The card shows a map of Ukraine with a highlighted region and a table of data.
- Cadastre Prioritization Tool:** Dynamically prioritize cadastres for demining. The card shows a map of Ukraine with a highlighted region and a table of data.
- Mine Action Resource Tracking:** Demining operator capacity tracking. The card shows a map of Ukraine with a highlighted region.
- Centre for Humanitarian Demining Toolbox:** Suite of CHD operational applications. The card shows a list of applications.
- Data Validation Inbox:** Data quality monitoring and alerts. The card shows a table of data.

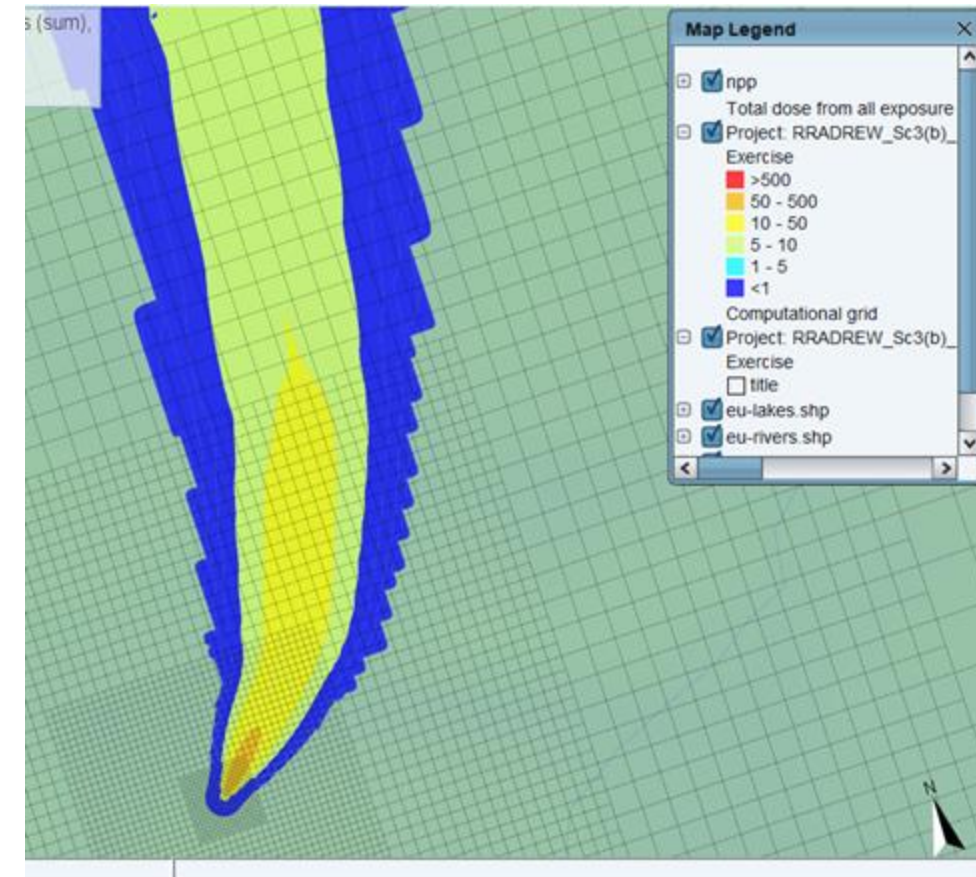
At the bottom of the interface, there are links for "Learn More" and "Get Support".

Scenario 1: Missile attack on a generating NPP

Evacuation - from 50 mSv

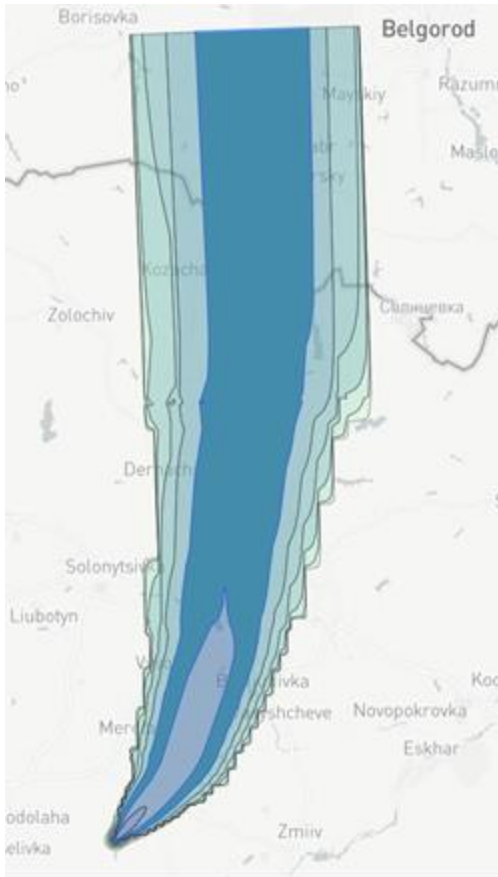
Sheltering - from 5 mSv

- attack occurred 2.5 hours after the unit shutdown
- depressurisation of 1.5% of fuel element cladding (~ 1 t of U235);
- isotope yield into the coolant: volatile -10%, medium -1%, heavy - 0.1%);
- 100% of RN released under the containment;
- release through a 100 m high ventilation pipe is from -10-100% of radioactive materials;
1 day after the accident.
- total RN release - **$3,5 \cdot 10^{16} \text{Bq}$**



SC 1: Evacuation (from 50 mSv)

Population affected - 1 512 417



HAZARDS

⚠ IMSMA Hazards 33

🔧 DSST Reports 23

🔧 SESU Tasks 297

AGRICULTURE

📍 Cadastres 59 444

€ Valuation 38 млрд грн

🚜 % Cultivated 5,9%

EDUCATION

🎓 Schools 282

👤 Students 88 156

👤 Teachers 6842

INFRASTRUCTURE

🏠 Buildings 70 841

🛣 Roads 4 046 km

🚂 Railways 610 km

Scenario 2: NPP in a cold shutdown

NPP is in a cold shutdown. Missile attack

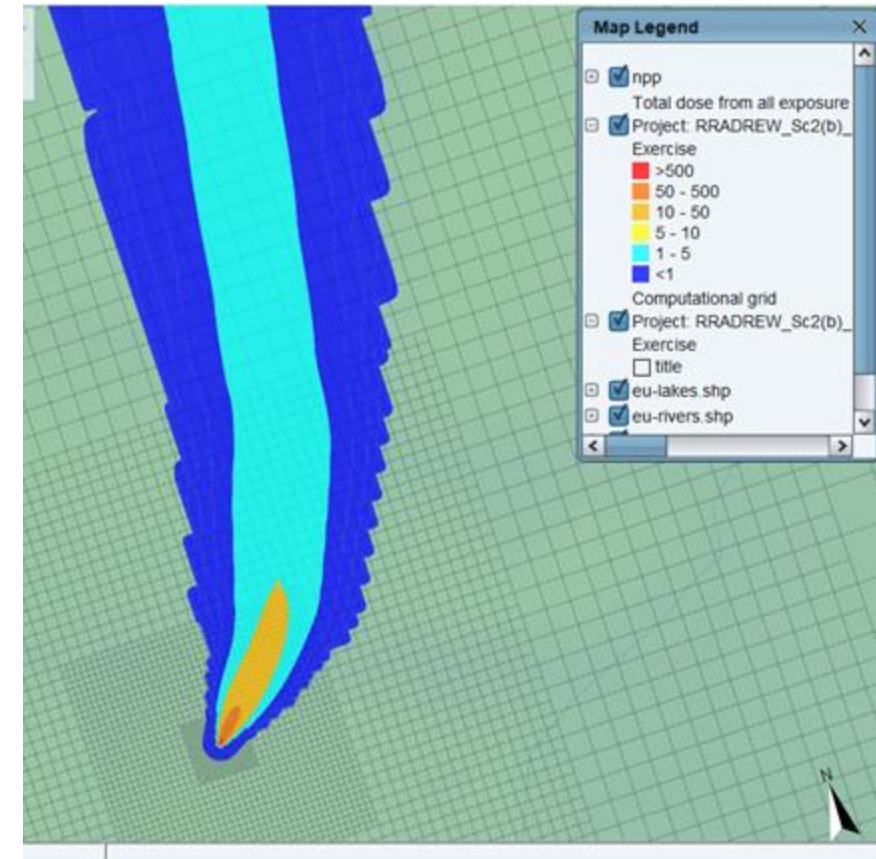
According to the matrix:

- NPP in a cold shutdown
- within 50 km of the combat line
- nuclear facility and its personnel are taken hostage
- 50% of the power grid is operational
- measures to notify the civilian population are complicated

Scenario 2: NPP in a cold shutdown

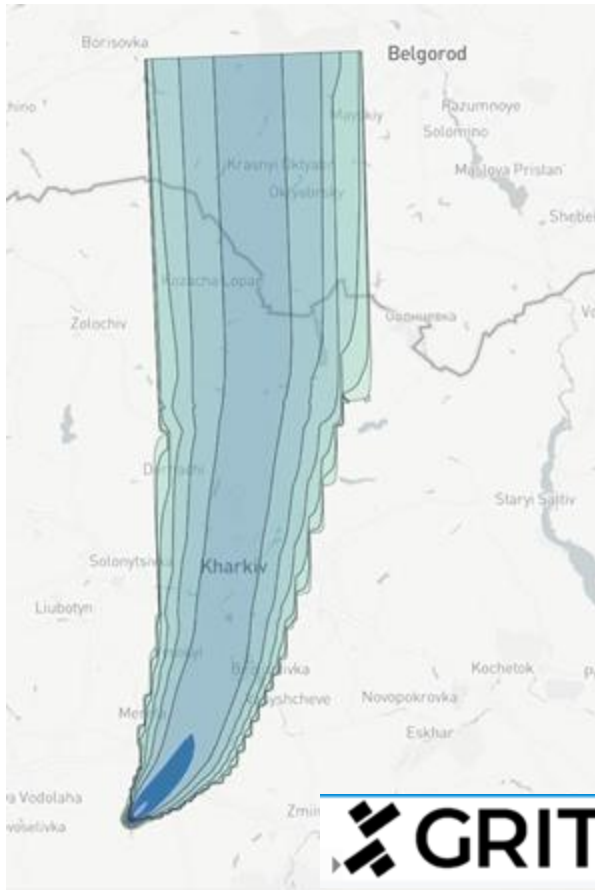
Population affected - 9 285

- shelling led to the complete destruction of the external power supply network;
- failure of the backup diesel power plants;
- depressurisation of **42 fuel assemblies** (~18,283 t of U235);
- isotope release to the coolant in the respective fractions: volatile - 10%, medium -1%, heavy - 0.1%),
- release under the containment (100%);
- release through a ventilation pipe (height 100 m) 10-100%.
- no more than **2 months after the shutdown**;
- total RN release - **$2,7 \cdot 10^{14} \text{Bq}$**



SC 2: Evacuation (from 50 mSv)

Population affected - 19 192



HAZARDS

⚠ IMSMA Hazards 0

🔧 DSST Reports 0

👤 SESU Tasks 1

EDUCATION

🎓 Schools 0

👤 Students 0

👤 Teachers 0

INFRASTRUCTURE

🏠 Buildings 886

🛣 Roads 183 km

🚂 Railways 35 km

AGRICULTURE

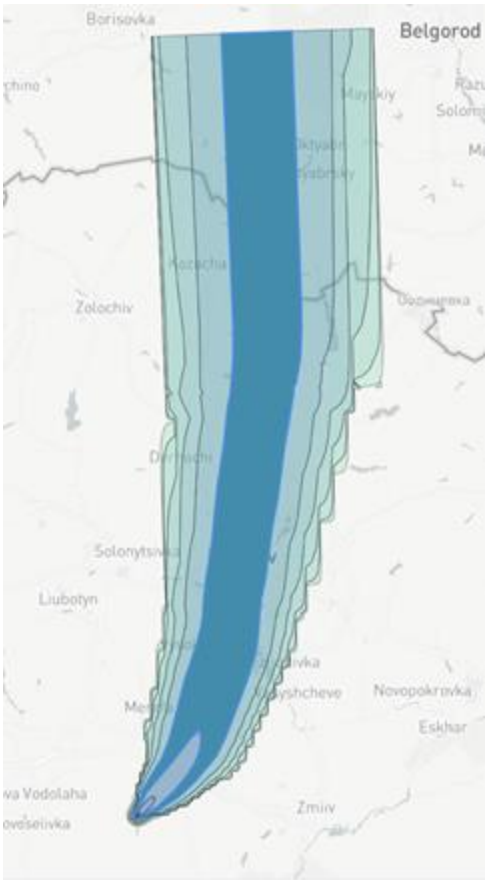
📍 Cadastres 689

€ Valuation 438 млн грн

🚜 % Cultivated 48,6%

SC 2: Sheltering (from 5 mSv)

Population affected - 1 325 023



HAZARDS

- ⚠ IMSMA Hazards 32
- 🔧 DSST Reports 13
- 🔧 SESU Tasks 239

AGRICULTURE

- 🏠 Cadastres 46 656
- € Valuation 29 млрд грн
- 🚜 % Cultivated 7,2%

EDUCATION

- 🎓 Schools 238
- 👤 Students 75 539
- 👤 Teachers 5888

INFRASTRUCTURE

- 🏠 Buildings 53 041
- 🛣 Roads 3 310 km
- 🚂 Railways 502 km

Quantitative assessment: scenarios to discuss and describe.

Scenario 3

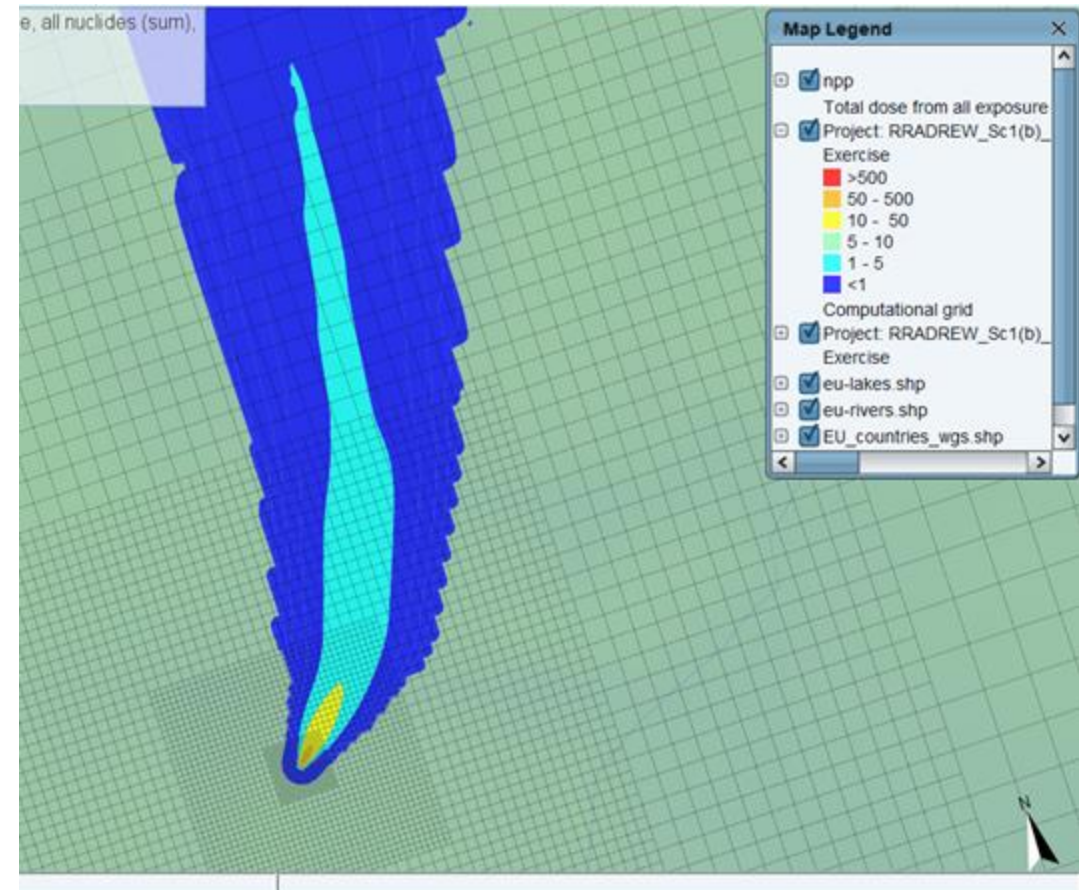
Shelling of the spent fuel storage facility with all means of destruction.

According to the matrix:

- spent fuel storage facility
- directly on the line of combat
- events that may occur during the movement of the front line past the territory of the nuclear facility
- 50% of the power grid is operational (or irrelevant)
- measures to notify the civilian population are complicated

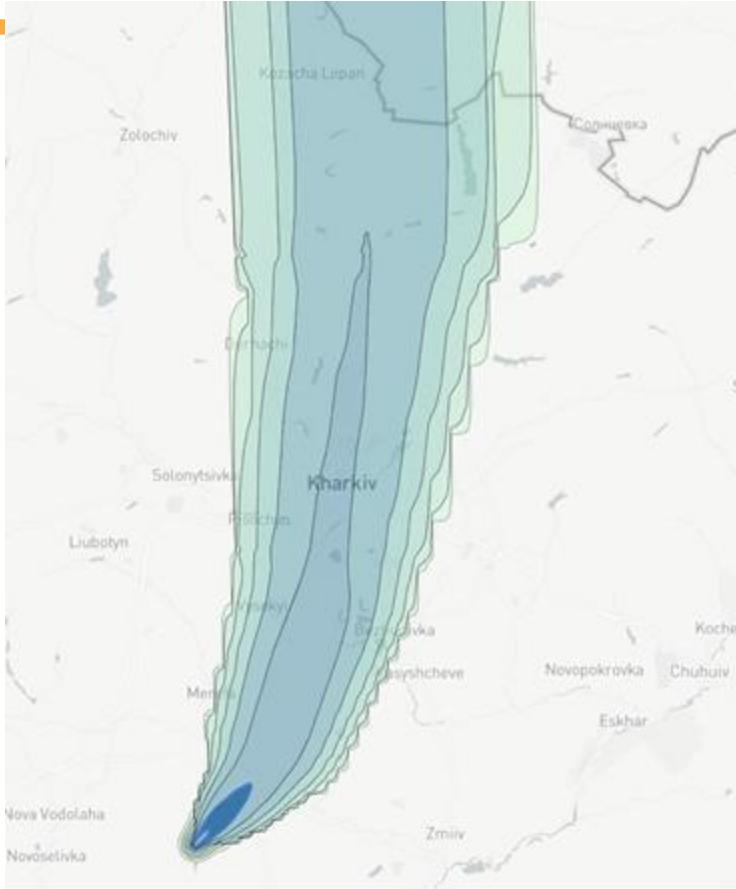
Scenario 3: Shelling of the spent fuel storage facility with all means of destruction.

- single spent fuel casks hit by missile or GBU attack on an open storage site
- the concrete container, metal basket where fuel assemblies are placed, is mechanically destroyed
- 31 fuel assemblies with 15 t U are destroyed.
- spent fuel is stored at the site for ~ 7 years after NPP shutdown
- release to the environment 50 % of volatile isotopes, 10 % of intermediate isotopes and 1 % of heavy isotopes of their activity in the destroyed fuel assemblies.
- spread of RN, carried by blast wave, will occur at a height and distance of about 100 m from the site of the spent fuel cask destruction



SC 3: Evacuation (from 50 mSv)

Population affected - 8 130



HAZARDS

⚠ IMSMA Hazards 0

🔧 DSST Reports 0

🔍 SESU Tasks 0

EDUCATION

🎓 Schools 0

👤 Students 0

👤 Teachers 0

AGRICULTURE

🏠 Cadastres 290

€ Valuation 90 млн грн

🚜 % Cultivated 80,5%

INFRASTRUCTURE

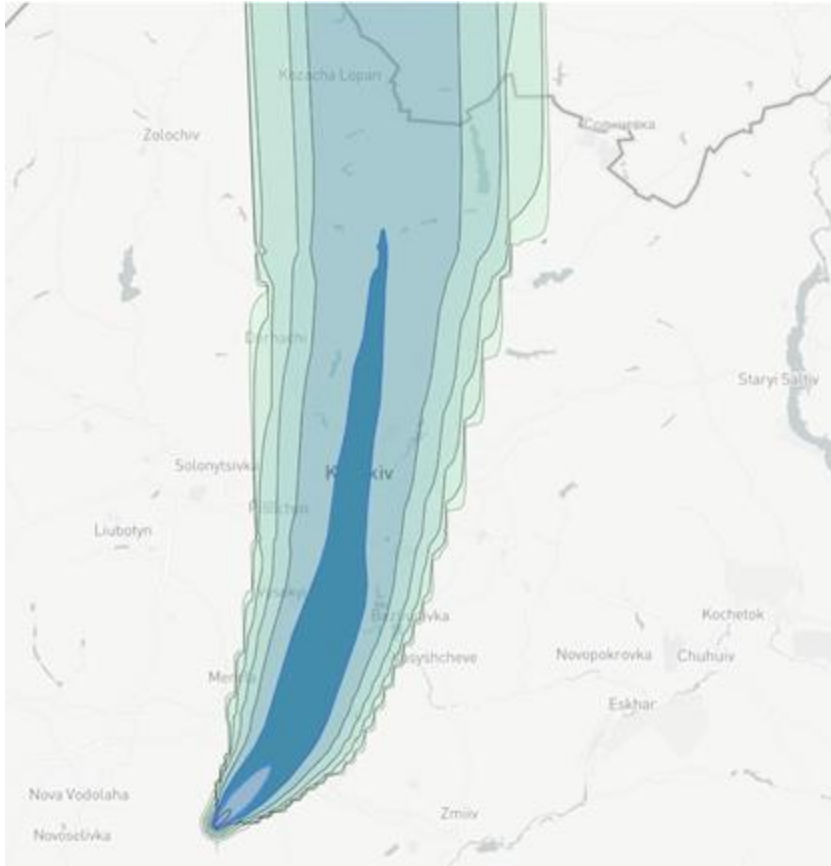
🏠 Buildings 415

🛣 Roads 102 km

🚂 Railways 24 km

SC 3: Sheltering (from 5 mSv)

Population affected - 984 417



HAZARDS

⚠ IMSMA Hazards 0

🔧 DSST Reports 1

🔍 SESU Tasks 51

AGRICULTURE

📍 Cadastres 17 458

€ Valuation 13 млрд грн

🚜 % Cultivated 23,4%

EDUCATION

🎓 Schools 111

👤 Students 30 887

👤 Teachers 2537

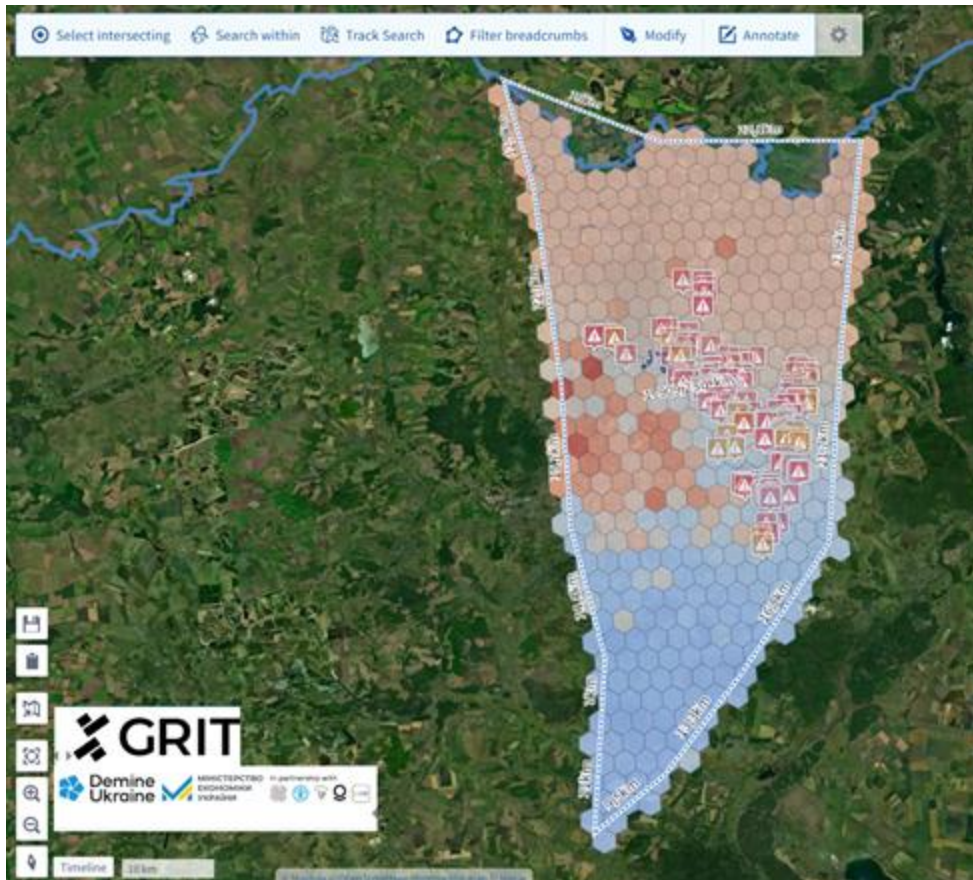
INFRASTRUCTURE

🏠 Buildings 19 619

🛣 Roads 1 687 km

🚆 Railways 210 km

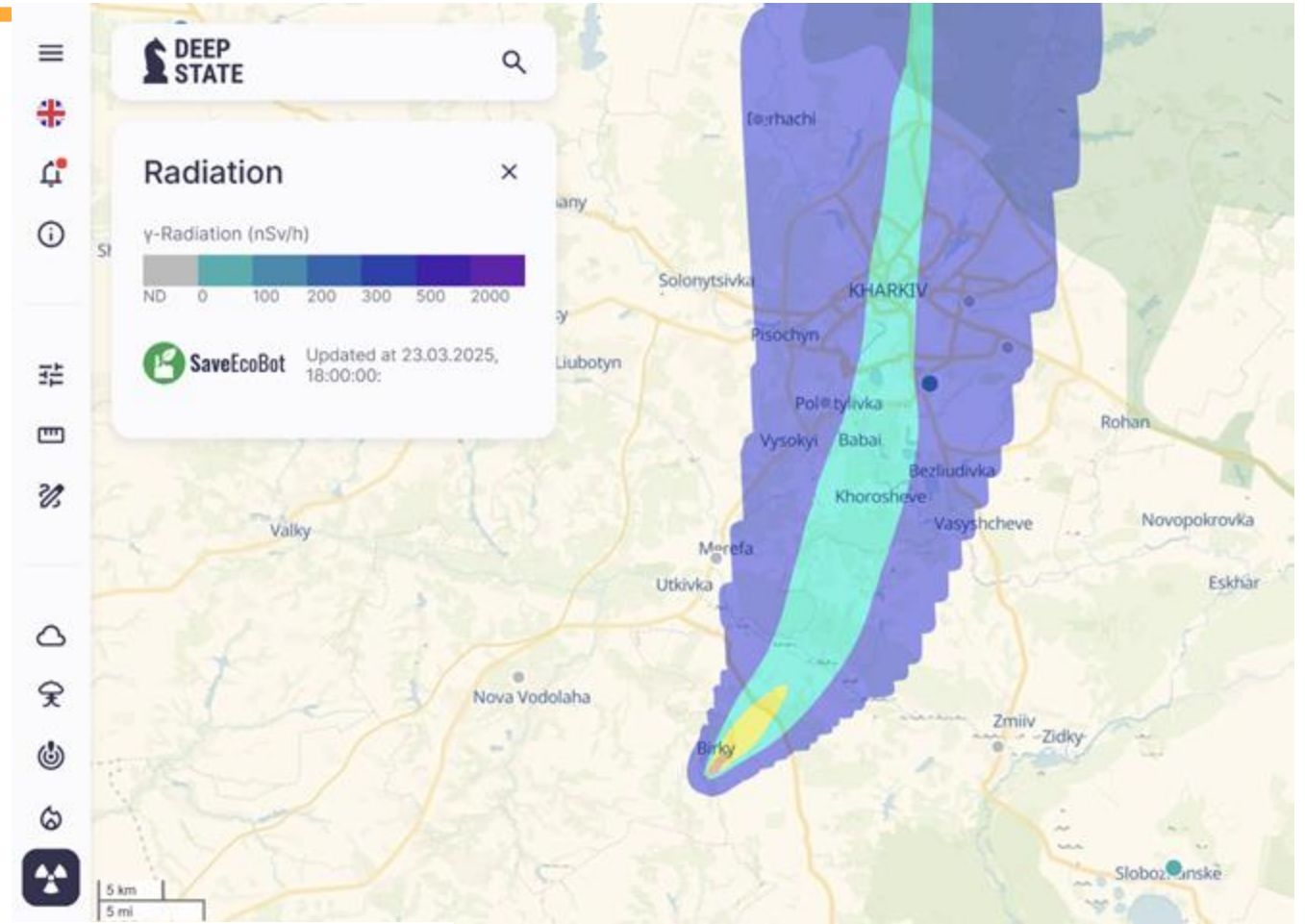
Limitations: Aggregate Risk Arithmetic



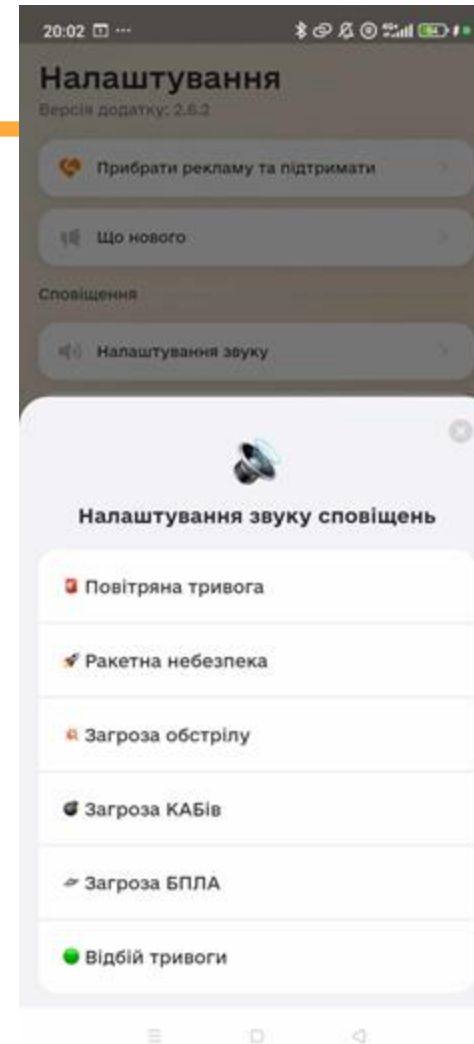
Limitations: Evacuation capacity

- 13 major road evacuation routes
- 9 railroad evacuation roads

North-east - frontline



Alerts for population



Means of resilience and preparedness

**ТРИВОЖНА ВАЛІЗА ДЛЯ ЕВАКУАЦІЇ
ІЗ ЗОНИ РАДІАЦІЙНОЇ АВАРІЇ**

МІНІСТЕРСТВО
ОХОРОНИ
ЗДОРОВ'Я
УКРАЇНИ

* зона евакуації буде визначена органами влади,
спираючись на прогноз масштабів аварії

- ✓ Документи та їхні копії.
- ✓ Змінний одяг та взуття.
- ✓ Маску для обличчя або респіратор.
- ✓ Мінімально необхідний запас води і їжі в герметичній упаковці.
- ✓ Аптечку і тижневий запас ліків (якщо ви маєте хронічні захворювання).
- ✓ Вологі серветки.

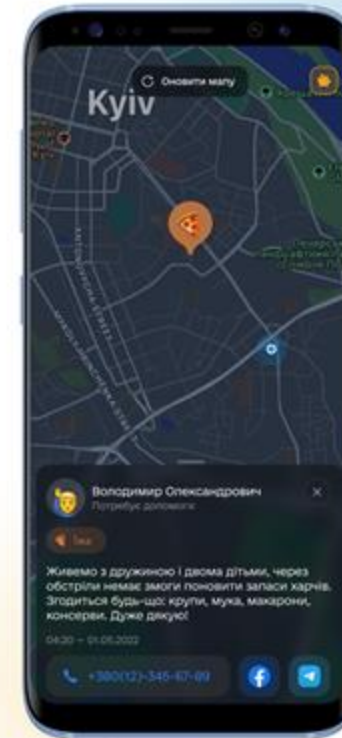
Щільно обмотайте валізу або наплічник харчовою плівкою або скотчем. Це значно полегшить процес їхньої дезактивації на санітарних постах.



apps to support
community
communication

recommendations
available
everywhere

Знайди допомогу
поблизу себе або стань у
нагоді сам 📍



Ераунд — взаємодія
українців та усіх
небайдужих





RRADEW

On behalf of all the RRADEW team

**Thank you for
your attention**

Risk matrix exercise:

