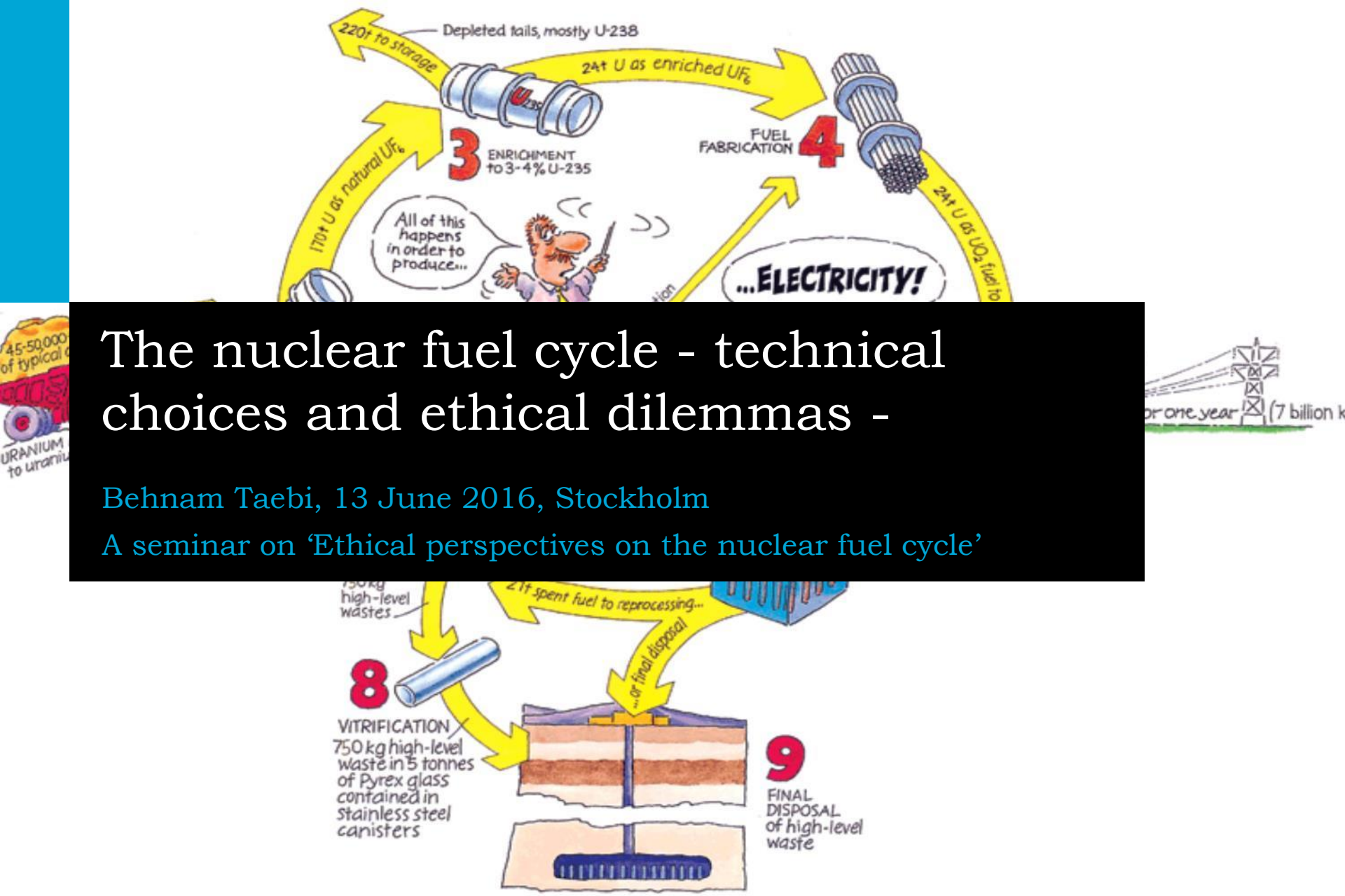


The nuclear fuel cycle - technical choices and ethical dilemmas -

Behnam Taebi, 13 June 2016, Stockholm

A seminar on 'Ethical perspectives on the nuclear fuel cycle'

What ethics got to do with it?

- Aren't these technical/political/legal decisions?
  - Which fuel cycle should a country choose?
  - What to do with the remaining spent fuel?
  - Where should spent fuel (or waste) be disposed of?
  - Should the waste be disposed of nationally or multinationally?
  - How deep underground and using which disposal method?
  - How much protection should we offer future generations?
  - What levels of radiation exposure do we deem acceptable?
  - (How) should we distinguish between different futures?
  - How to choose a host community? How to "compensate" for extra burden?

Ethics of nuclear energy

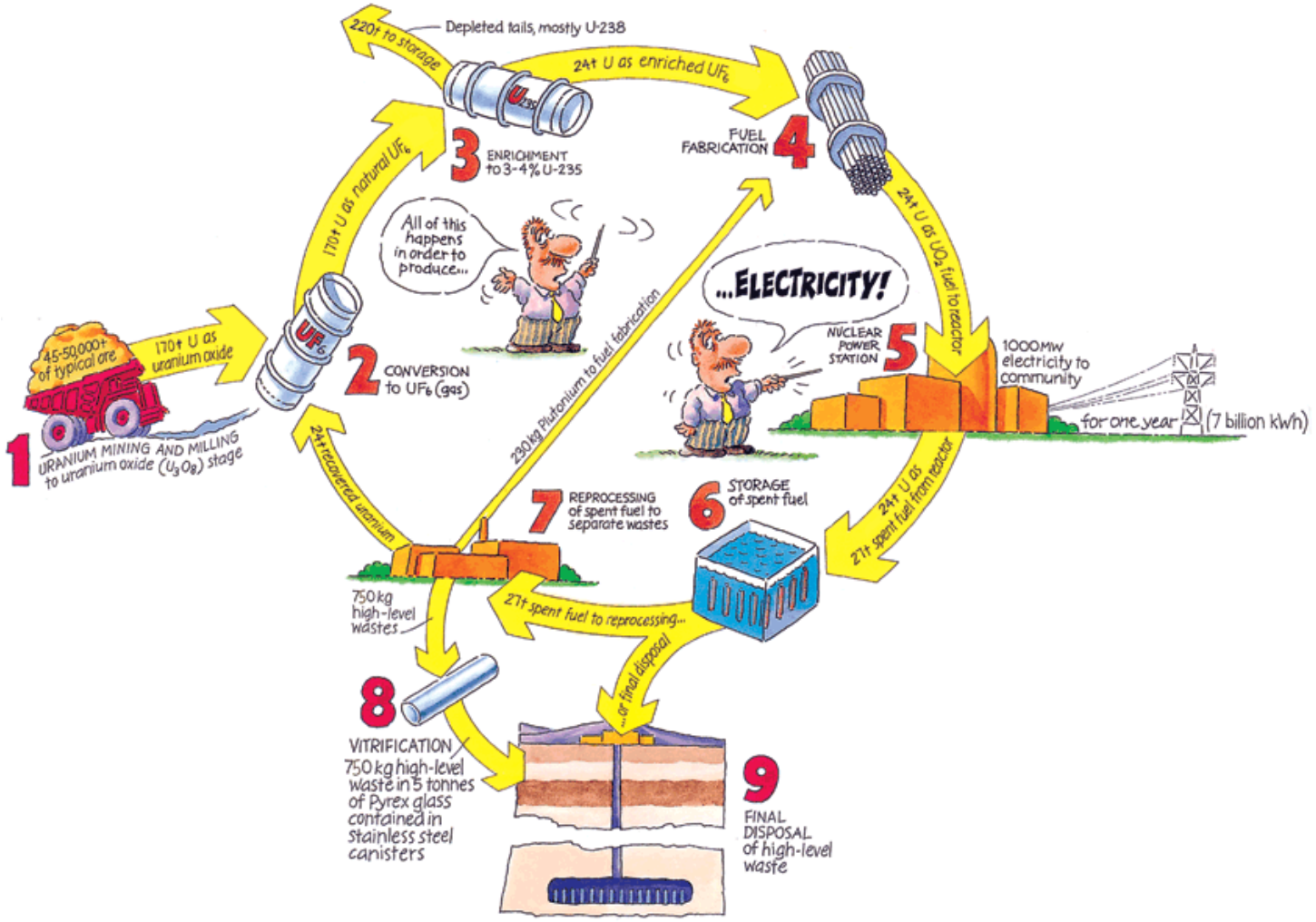
- What is ethics
  - A systematic reflection on right and wrong, just or unjust etc.
  - Each of these questions are essentially a technical question, or a question for the political decision-makers (at the local, national, European or broader international: e.g. IAEA)
  - But every single question has an evident moral dimension
  - This morality is not always appreciated as such, but this doesn't make the question less morally laden

Values at stake: e.g. safety

- In technical design and with respect with technology, safety has always been a key issue
  - What levels of safety do we require for nuclear reactors
  - Probabilistic Assessments and likelihoods of one in every 100,000 to 1,000,000 years
  - Why do we find a certain probability acceptable in policy-making?
  - What levels of consequences do we find acceptable? For whom?
  - Long-term safety of nuclear waste (I will discuss later)
- In addition to safety, security, sustainability, economic feasibility, resource durability

Security and non-proliferation

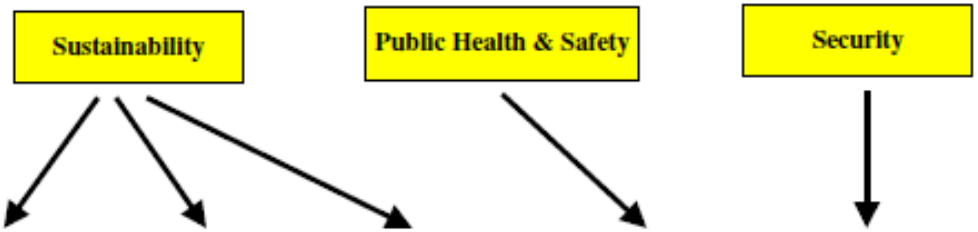
- Dual use technologies (enrichment and reprocessing) and security of fissile materials (233U, 235U, 239Pu, etc.)
  - The Nuclear Security Summits
- Each existing and future fuel cycles would affect security differently
- Non-proliferation of nuclear weapons and access to each of these dual use technologies
  - The Non-Proliferation Treaty, its additional protocols and signatories


Depleted tails, mostly U-238
220t to storage
24t U as enriched UF6
3 ENRICHMENT to 3-4% U-235
FUEL FABRICATION 4
170t U as natural UF6
All of this happens in order to produce...
...ELECTRICITY!
24t U as UO2 fuel to reactor
45-50,000t of typical ore
170t U as uranium oxide
2 CONVERSION to UF6 (gas)
NUCLEAR POWER STATION 5
1000Mw electricity to community
for one year (7 billion kWh)
1 URANIUM MINING AND MILLING to uranium oxide (U3O8) stage
230kg Plutonium to fuel fabrication
24t recovered uranium
7 REPROCESSING of spent fuel to separate wastes
6 STORAGE of spent fuel
24t U as 27t spent fuel from reactor
750kg high-level wastes
27t spent fuel to reprocessing...
...or final disposal
8 VITRIFICATION 750kg high-level waste in 5 tonnes of Pyrex glass contained in stainless steel canisters
9 FINAL DISPOSAL of high-level waste

Does ethics only *ask* questions?

- Each nuclear fuel cycle affect each value differently
  - This gives rise to certain moral dilemmas that need to be resolved
- I will present some of my defended arguments with respect of the ethical issues associated with nuclear fuel cycle

Moral dilemmas of nuclear cycle



	Supply certainty		Radiological risks to environment		Affordability		Radiological risks to public		Proliferation	
	Short	Long	Short	Long	Short	Long	Short	Long	Short	Long
Open	+	-	+	-	+	-	+	-	+	-
Closed	+	+	-	+	-	+	-	+	-	+

- Essentially, the open cycle seems to be most beneficial for the present generations while the closed cycle reduces long-term concerns and is, hence, better for future generations

Source: Taebi, B. and J. L. Kloosterman. 2008. To Recycle or Not to Recycle? An Intergenerational Approach to Nuclear Fuel Cycles. *Science and Engineering Ethics* 14 (2):177-200.

Morally desirable cycle

- Is the cycle that reduces the waste life-time substantially
- A future cycle that helps reduce waste life-time to 500-1,000 years (the so-called Partitioning and Transmutation) is the most morally defensible cycle
- Swedish nuclear waste disposal acknowledges the existence of such future (physically possible but not yet industrialized) cycle: retrievability

Source: Taebi, B. 2011. The Morally Desirable Option for Nuclear Power Production. *Philosophy & Technology* 24 (2): 169-192.

International perspectives

- Nuclear energy is essentially a multinational endeavour
  - E.g. uranium sources, reactor producers, fuel suppliers
- Multilateral/multinational collaborations are increasing
  - Both in fuel leasing programs (e.g. Russia)
  - And in spent fuel storage and final disposal (e.g. ERDO)
- More nuclear energy producing countries will be joining in the next couple of decades
  - In Europe, we wrongly assume that nuclear energy is dieing a slow death

National or multinational waste

- Even though Swedish law doesn't allow for receiving or exporting nuclear waste, some other European countries (including Denmark) are considering multinational disposal

- Ethically speaking, waste is each country' own responsibility
  - But there are good reasons for multinational disposal
  - Lack of suitable rock formation, safety and economic benefits
  - Who exports to whom? Under what ethical conditions?

Global dispersal of nuclear energy

- Currently 30 countries produce nuclear energy
- Another 45 countries are potentially interested
  - Of course wanting and being able to are two different things
- The Russian proposal: an offer you can't refuse
  - Build, Own, Operate
  - Similar efforts in China.
  - The targets are mostly developing countries
- Nuclear energy is increasingly becoming international
  - Ethics and governance challenges

Appreciating ethics

- Acknowledging ethical issues of nuclear energy production and nuclear waste disposal as such could help make better informed technical and political choices as well as regulations and regulatory frameworks

- Ethics is interwoven with these choices
  - Even if we don't immediately see the ethical issues at stake
  - E.g. long-term protection of spent fuel in the licenses of the American Environmental Protection Agency

Thanks you

- Questions and comments are appreciated. Now or in the future

http://ethicsandtechnology.eu/taebi

b.taebi@tudelft.nl