



TYPE ONE ENERGY

***CSA methodological approach for
calculating tritium derived release
limits and the CANDU experience***

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What Is Type One Energy?

High-field stellarator fusion pilot plant (FPP) design from the start

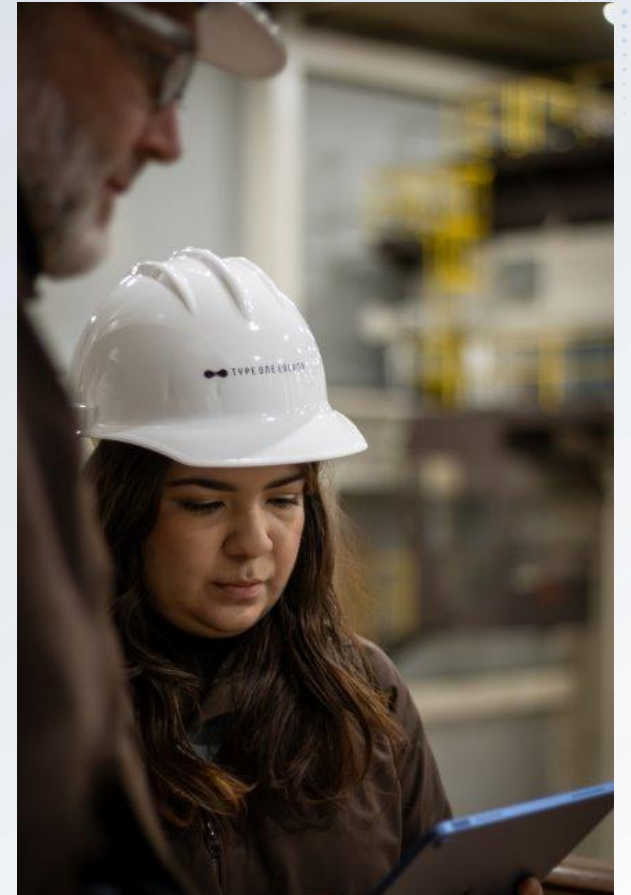
Net-electricity on a decadal time scale, consistent with the US Government

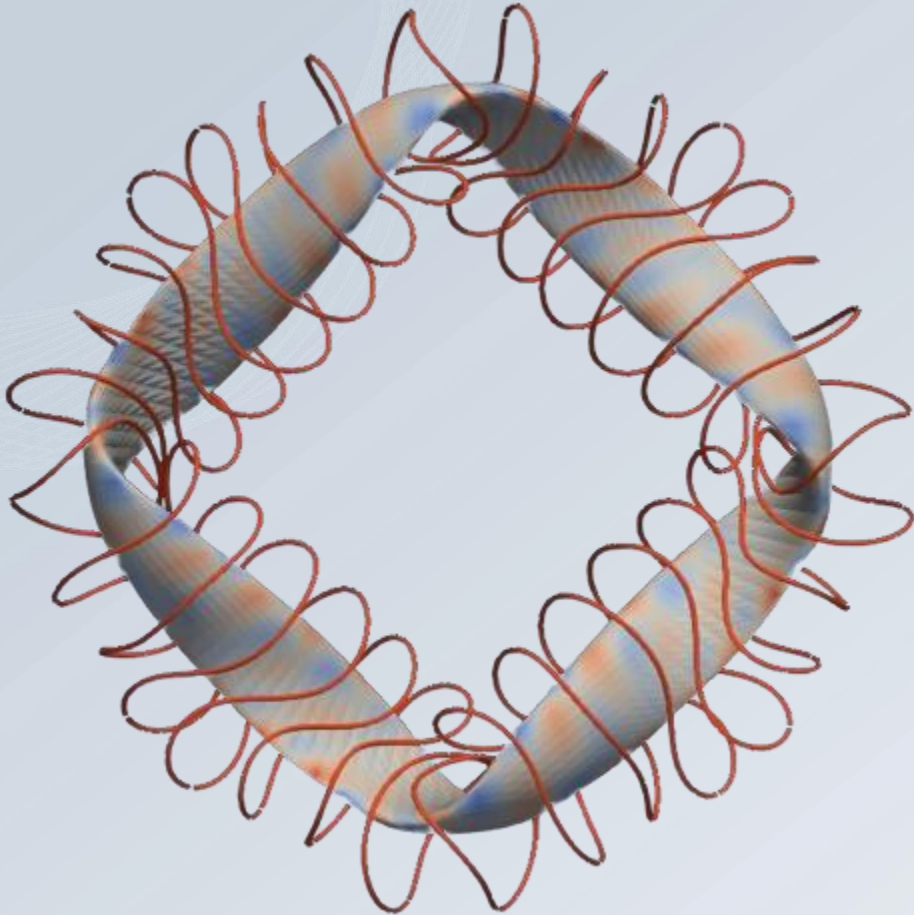
Bold Decadal Vision

Enabled by recent advances in demonstrated stellarator performance, theory & simulation, and high temperature superconducting (HTS) magnets

T1E has grown significantly in the last year, fully financed for the near future:

- \$82M seed-funding
- Awardee of US DOE Milestone-Based Fusion Development Program
- >140 employees in 4 office locations in US (Madison, WI; Woburn, MA; Oak Ridge, TN) and Canada (Vancouver, BC)



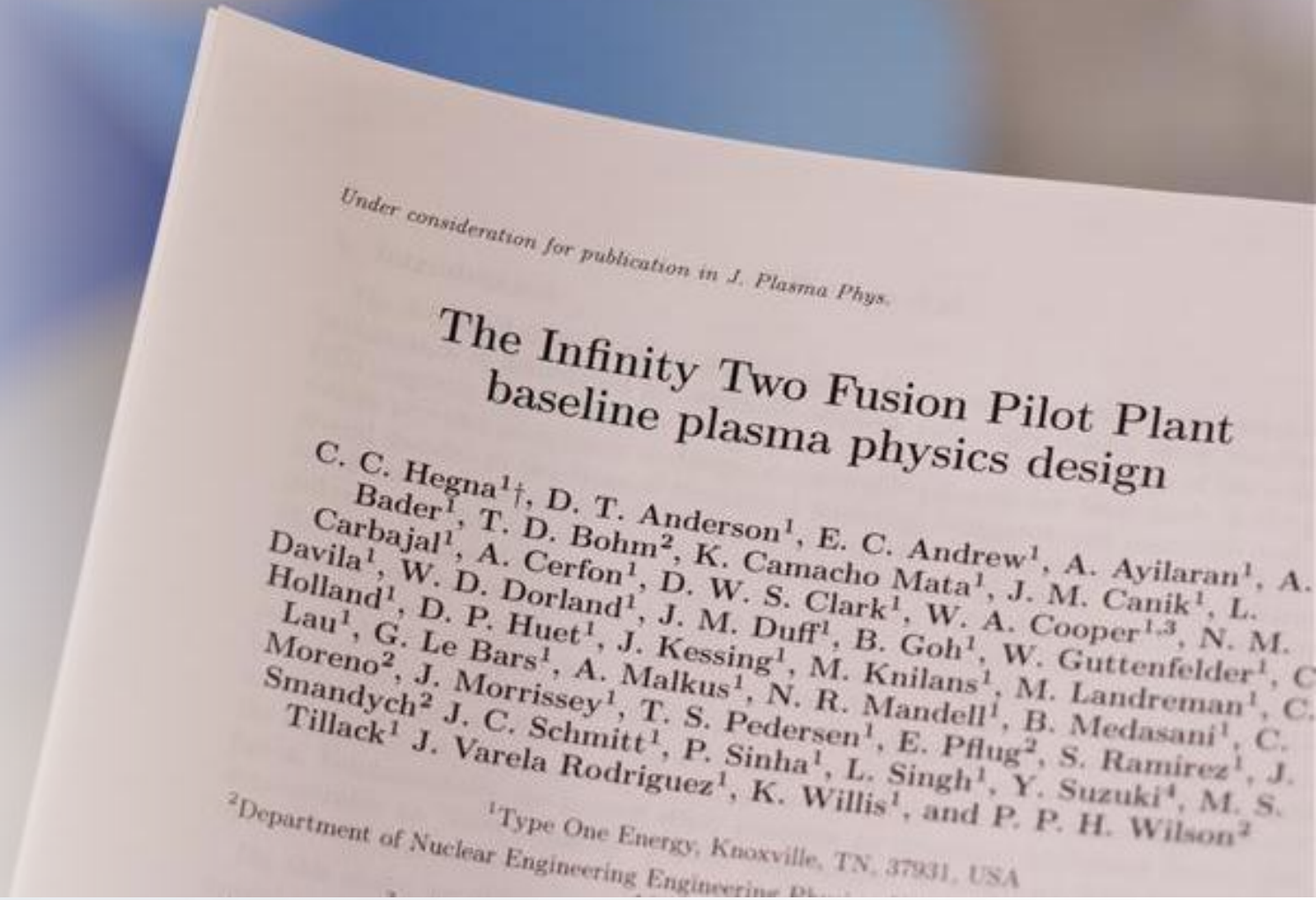


What are they? A stellarator is a type of fusion device designed to generate energy by confining superheated plasma using twisted, complex magnetic fields—without relying on electric currents like some other fusion systems.

Why are they so special? Unlike other fusion concepts, stellarators can be designed to be inherently stable and can operate continuously, making them a promising pathway for reliable, commercial fusion power.

How do they work? The unique, carefully engineered shape of a stellarator's magnetic coils keeps the plasma stable, allowing fusion reactions to occur more efficiently while reducing the risk of disruptions.

- We recently published the most detailed physics basis for stellarator fusion to date.
- The findings show **there are no scientific barriers to achieving fusion**—proving that the science is sound.
- This marks a turning point from experimental research to real-world engineering.

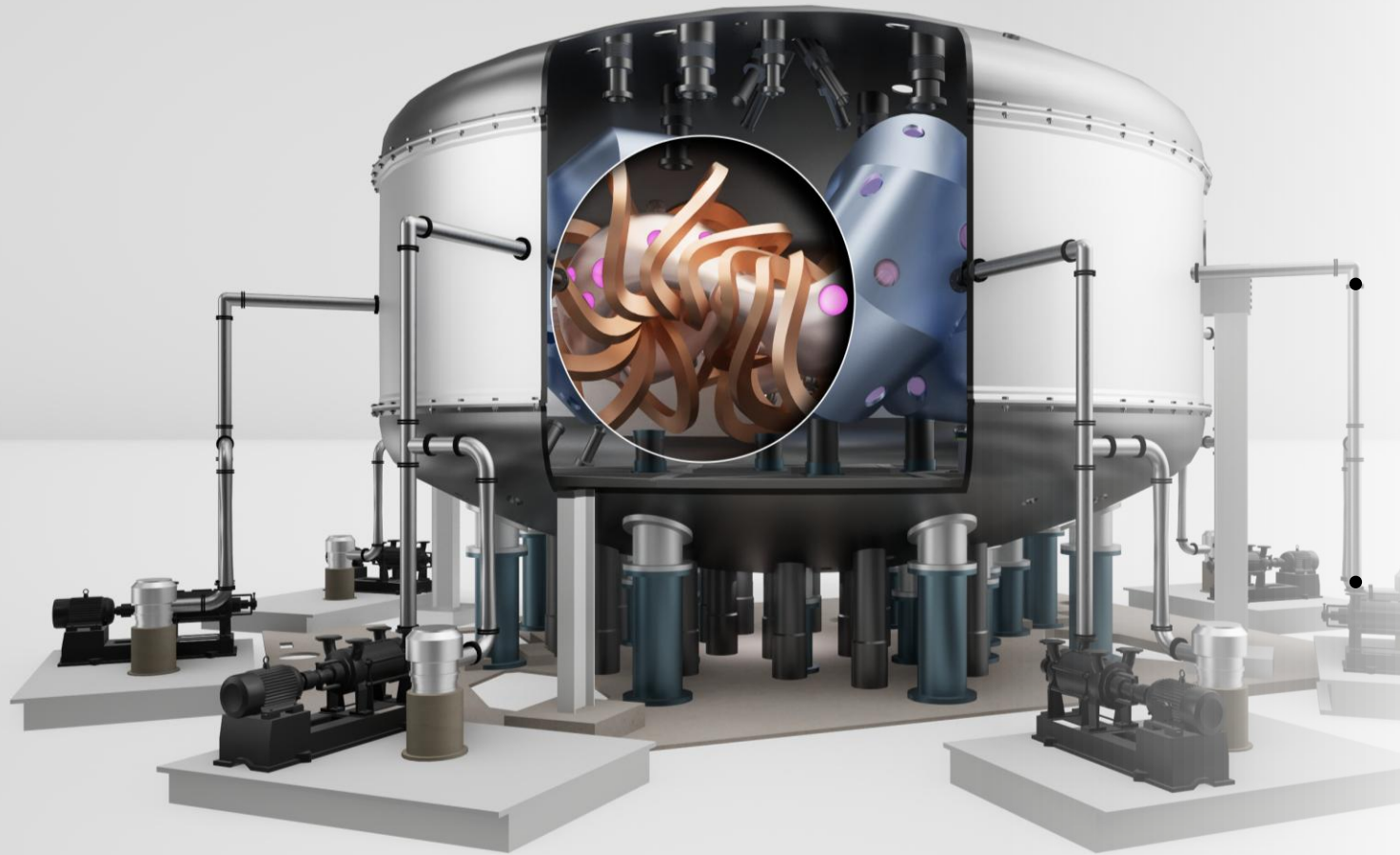


- We have **successfully completed and tested a prototypical magnet for our first fusion device, Infinity One.**
- This is one of the most complex and critical engineering components—and it's now proven.
- It demonstrates that we're not just planning—we're actively building the future of energy.





- Infinity One is being built at the now retired Bull Run Fossil Plant, transforming a former coal site into a hub for clean energy innovation.
- Will invest at least \$230M in Infinity One
- Construction to begin in 2026. Completion and start of operations in late 2028.
- **It aligns with the State of Tennessee's Nuclear Fund investments** and the regional push to develop a world-leading energy corridor.



- In partnership with TVA, we are preparing for construction of Infinity One and planning for our future fusion power plant, Infinity Two.
- Our work will create high-quality jobs, attract investment, and **build long-term economic value in the region.**
- We look forward to continued collaboration with industry, government, and community leaders to **realize this shared vision.**

DRL Concept in 1 Slide

Approach to Regulating Routine Releases

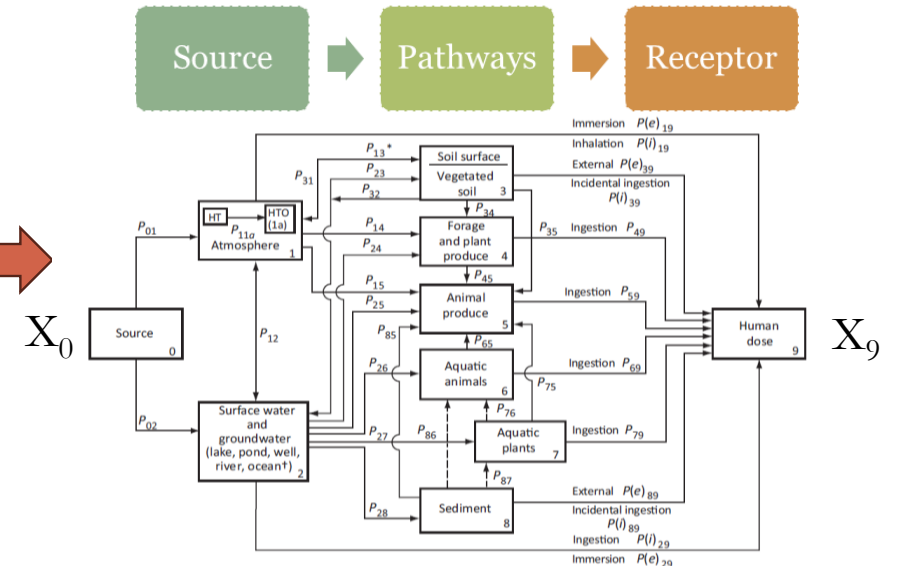
- It is possible for any nuclear application, fission or fusion, to have routine releases which are regulated under their license conditions
- It is desirable to have a numerical value for allowed releases consistent with the public dose limit as a basis to compare against release and environmental monitoring
- One approach is to use Derived Release Limits (DRLs) *Adapted from CSA N288.1-14 (2014)*

Model has been validated with decades of heavy water reactor operations

The Advantage

- DRLs are a systematic and defensible way to verify compliance with public dose limits
- Based on source, receptor and pathways
- Use site-specific parameters when possible
- Calculate DRLs before a facility operates
- Perform environmental baseline study
- Environmental monitoring program is used to verify releases are below DRLs
- Can be readily updated if site-specific or input parameters change

Environmental Transfer Model



The Concept

- You calculate the **dose per unit release** using activity in compartments (X) and transfer parameters (P) between compartments
- The DRL is the ratio of the dose limit (i.e., public dose limit) to the dose per unit release for all pathways considered

$$DRL = \frac{\text{Dose limit}}{\left[\frac{X_9}{X_0} \right]} \frac{Bq}{s} \frac{\frac{Sv}{yr}}{\frac{Sv}{yr} / \frac{Bq}{s}}$$

Canadian nuclear facilities use Canadian Standards Association (CSA) Guidance for defining release limits for routine operations

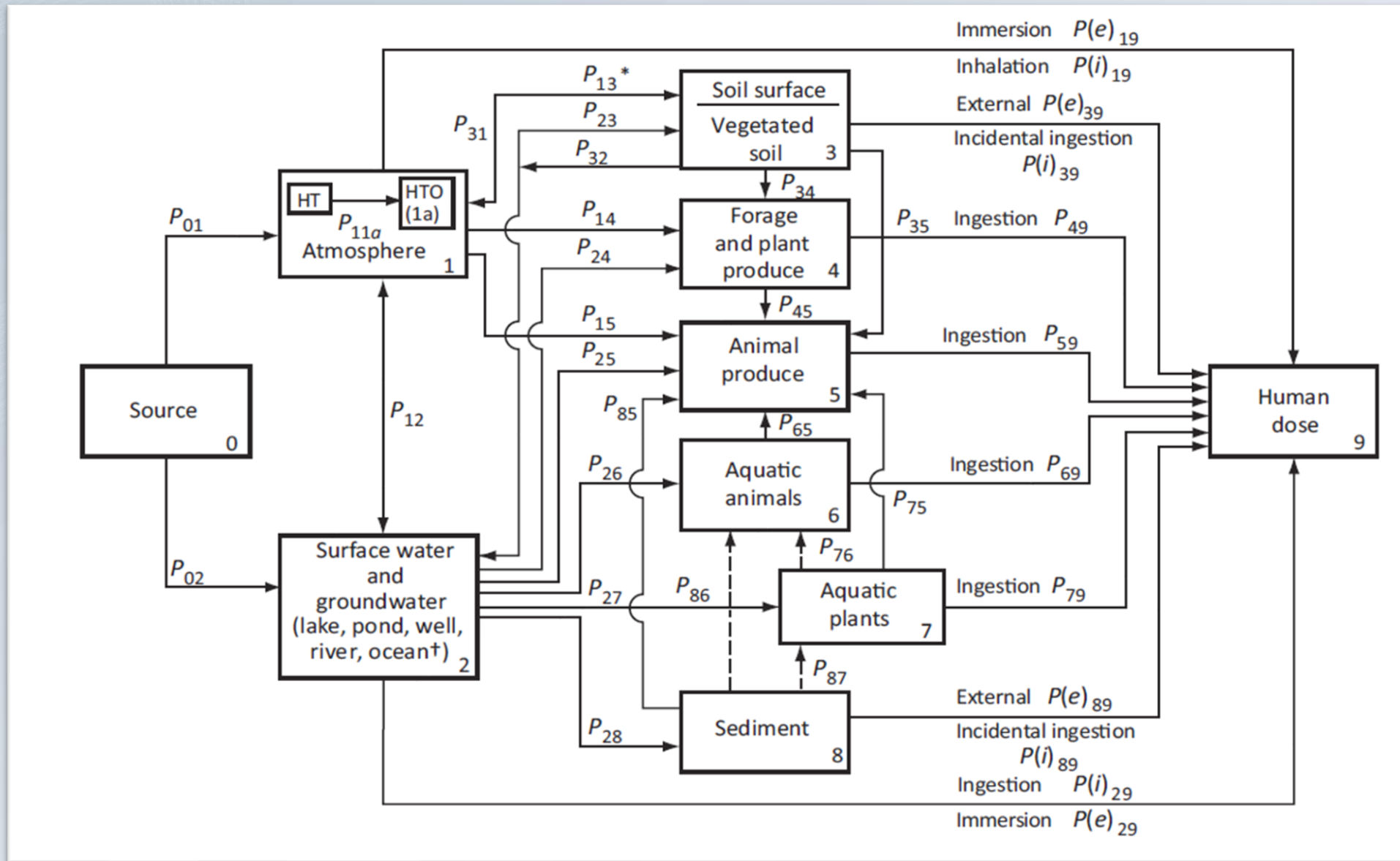
- The CSA methodology utilizes an environmental transfer model:
 - Identify the **representative radionuclides** to be considered for calculating the DRLs
 - Identify the **representative person** and the associated **exposure pathways** based on the existing site-specific data and using an environmental transfer model
 - Calculate **transfer parameters** based on generic and site-specific data
 - Calculate the pathway **doses per unit annual release** for each radionuclide released from the facility (airborne and liquid releases)
 - Calculate a **Derived Release Limit** (activity/time) based upon the above pathway dose per unit release and a dose constraint or limit
- Canada Deuterium Uranium (CANDU) reactors are exceptionally proficient at producing tritium, since the primary loop and moderator is heavy water (${}^2\text{H} + {}^1_0\text{n} \rightarrow {}^3\text{H}$)
- Therefore there are decades of experience in Canada dealing with tritiated systems, and the CSA approach considers unique aspects of tritium in the environment



CSA N288.1:14
(reaffirmed 2019)

Guidelines for calculating derived release limits for radioactive material in airborne and liquid effluents for normal operation of nuclear facilities



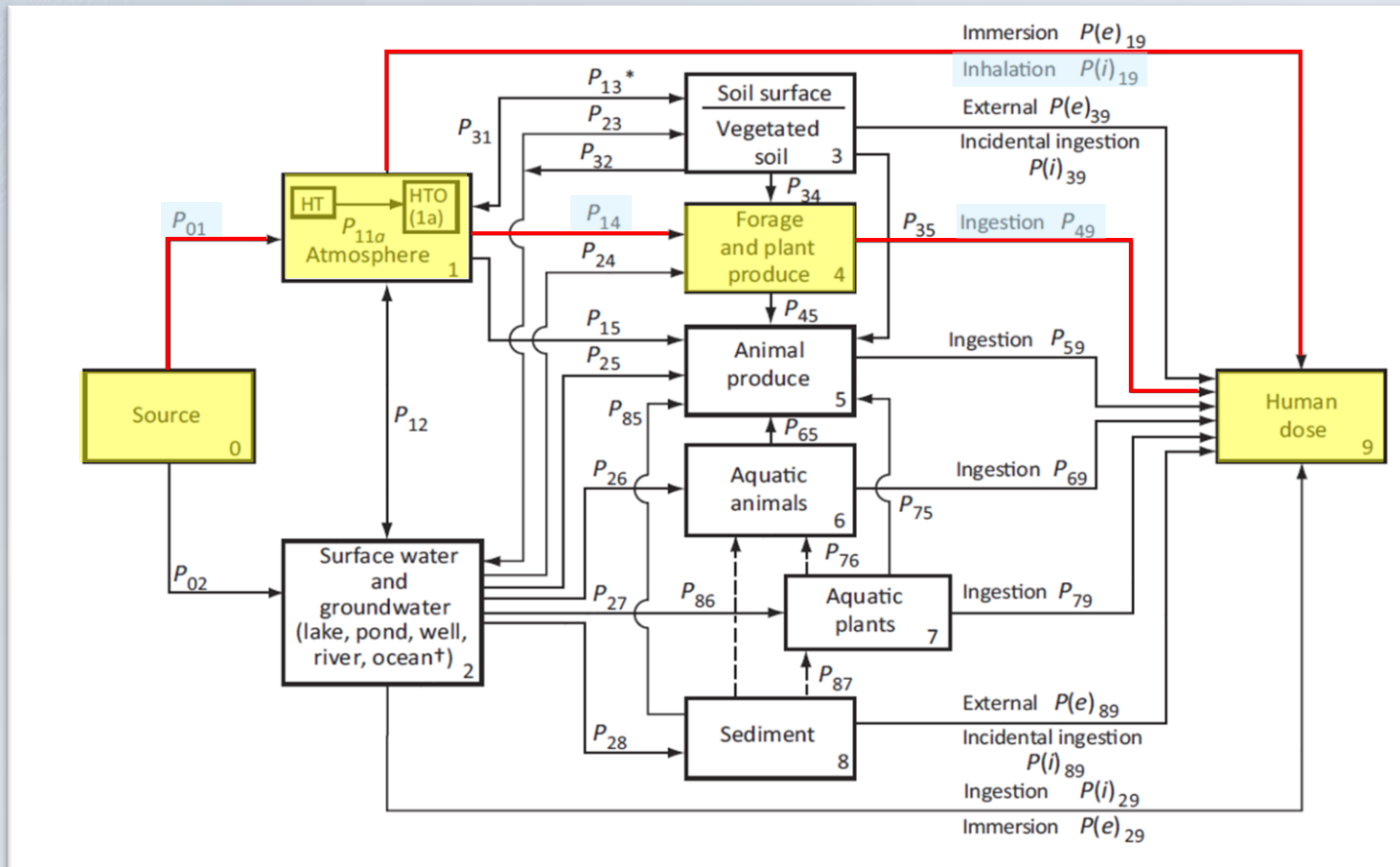


Look at a very simple case

Determine DRL for a representative adult at the boundary of a facility for airborne release of HTO only (*ignore OBT*)

Receptor is adult located at boundary 1 km downwind; 10 metre stack height

Assume the only pathways are (i) direct inhalation and (ii) food eaten from the boundary from local crop produce



- Only need to consider:
- Compartments 0, 1, 4 and 9
 - Transfer factors P_{01} , $P(i)_{19}$, P_{14} and P_{49}

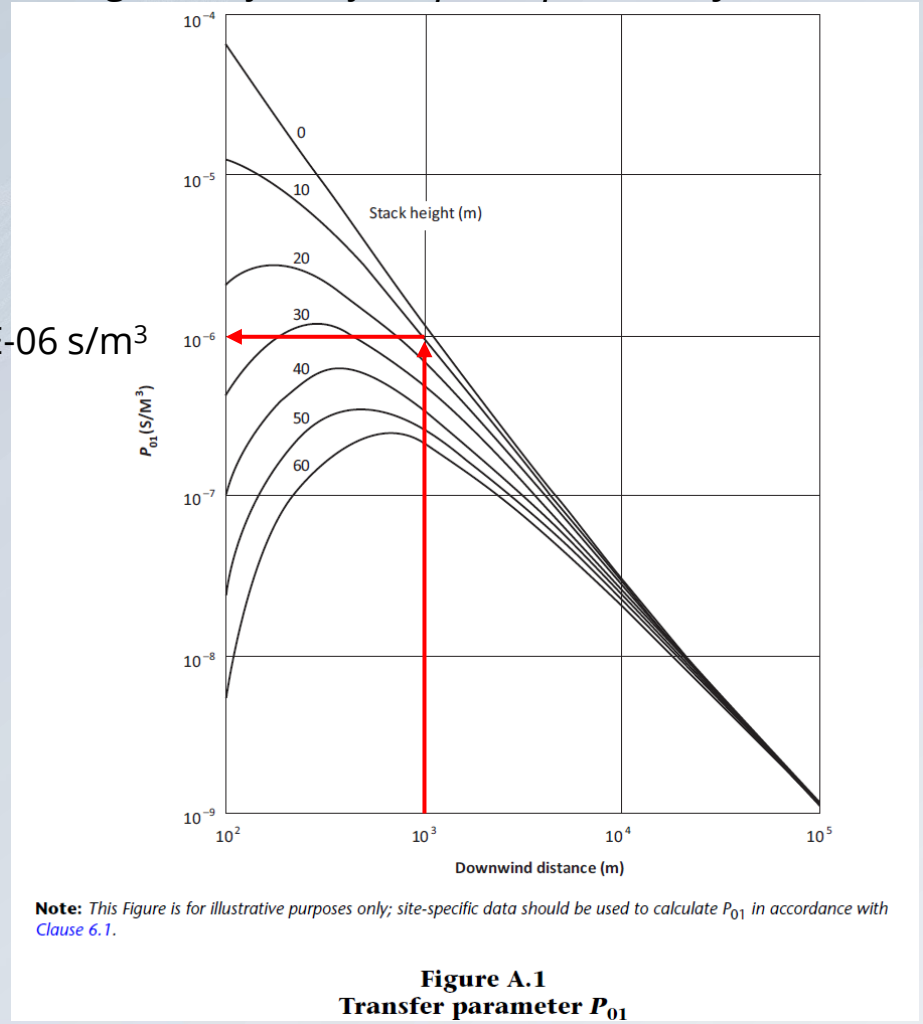
In the interest of time we will only do the complete solution for air inhalation

Simple case (cont)

Assumptions and generic data
(we are not solving these from first principles today)

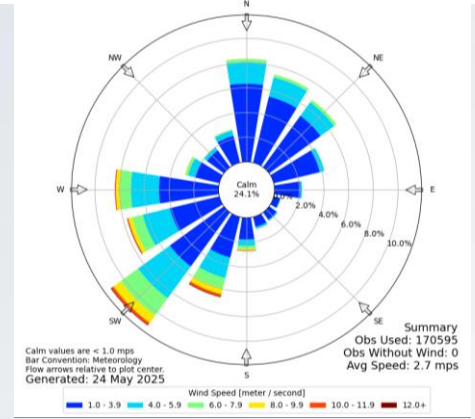
First, P_{01} :

$P_{01} \sim 1E-06 \text{ s/m}^3$



To solve it for a specific site, we need to solve a Gaussian dispersion equation using site specific values for wind rose, surface roughness, etc.

$$(P_{01})_j = \frac{\sqrt{2}}{\sqrt{\pi} X \Delta \theta} \sum_{i,k} \left[\frac{F_{ijk} D_k}{u_k \sum z_i} \exp\left(\frac{-H_{ik}^2}{2 \sum z_i^2}\right) \right]$$



Then, $X_1 = P_{01} X_0$

(recall we do not need the value of X_0 , since we are calculating X_9/X_0)

Now, $P(i)_{19} = \text{Breathing rate (m}^3/\text{yr)} * \text{DCF (Sv/Bq)}$

- 95th percentile adult breathing rate = 8400 m³/yr
- HTO Adult Type V Inhalation DCF = 3E-11 Sv/Bq

Therefore:

- $P(i)_{19} = (8400 \text{ m}^3/\text{yr}) * (3\text{E-}11 \text{ Sv/Bq}) = 2.52\text{E-}07 \text{ Sv/yr per Bq/m}^3$

Finally:

- $[X_9/X_0] = P_{01} * P(i)_{19} = (1\text{E-}06 \text{ s/m}^3) * (2.52\text{E-}07 \text{ Sv/yr per Bq/m}^3) = 2.52\text{E-}15 \text{ Sv/yr per Bq/s}$

Therefore, the DRL (*for this simple limited case*) is:

$$\text{DRL} = (1\text{E-}3 \text{ Sv/yr}) / (2.52\text{E-}15 \text{ Sv/yr per Bq/s}) = 4\text{E+}11 \text{ Bq/s} = \underline{1.25\text{E+}19 \text{ Bq/yr} = 3.38\text{E+}8 \text{ Ci/yr} = 34900 \text{ gram/year}}$$

DRLs are an exercise in obtaining as much site-specific data as you can, knowing as much about your receptors and their habits as you can, and doing the accounting

pathway

Considering only release of HTO

An example where we are considering local gardening (fruits and vegetables), personal farming (poultry; chicken meat and eggs), drinking local cow's milk (cows consume local forage), have a dug well for drinking, bathing and filling a swimming pool and the animals are watered by a local pond.

We are considering both HTO and OBT in the environment.

$X_9 / X_{0(a)} = P_{01} \{P(i)_{19}$	1
+ $P_{13spw} P_{3spw2w} P(e)_{2w9}$	2
+ $P_{13spw} P_{3spw2w} P(i)_{2w9}$	3
+ $P_{12p} P_{2p5_HTO} (poultry) P_{59_HTO} (poultry)$	4
+ $P_{12p} P_{2p5_OBT} (poultry) P_{59_OBT} (poultry)$	5
+ $P_{13spw} P_{3spw2p} P_{2p5_HTO} (poultry) P_{59_HTO} (poultry)$	6
+ $P_{13spw} P_{3spw2p} P_{2p5_OBT} (poultry) P_{59_OBT} (poultry)$	7
+ $P_{15_HTO} (poultry) P_{59_HTO} (poultry)$	8
+ $P_{15_OBT} (poultry) P_{59_OBT} (poultry)$	9
+ $P_{12p} P_{2p5_HTO} (cow's milk) P_{59_HTO} (milk)$	10
+ $P_{12p} P_{2p5_OBT} (cow's milk) P_{59_OBT} (milk)$	11
+ $P_{13spw} P_{3spw2p} P_{2p5_HTO} (cow's milk) P_{59_HTO} (milk)$	12
+ $P_{13spw} P_{3spw2p} P_{2p5_OBT} (cow's milk) P_{59_OBT} (milk)$	13
+ $P_{14} (forage) P_{45_HTO} (cow's milk) P_{59_HTO} (milk)$	14
+ $P_{14} (forage) P_{45_OBT} (cow's milk) P_{59_OBT} (milk)$	15
+ $P_{15_HTO} (cow's milk) P_{59_HTO} (milk)$	16
+ $P_{15_OBT} (cow's milk) P_{59_OBT} (milk)$	17
+ $P_{14_HTO} (fruit and veg) P_{49_HTO} (fruit and veg)$	18
+ $P_{14_OBT} (fruit and veg) P_{49_OBT} (fruit and veg) \}$	19

- The NPP utilities in Canada report measured emissions and compare them against site-specific DRLs
- The DRLs are based upon a 1 mSv/yr (100 mRem/yr) annual dose limit to a member of the public
- DRLs are based on very conservative assumptions

Facilities	Gaseous Emissions - Ci/yr (2006)				Gaseous Emissions - grams H-3/yr (2006)			
	HTO	% DRL	DRL	Release limit for dose constraint (10% of DRL)	HTO	% DRL	DRL	Release limit for dose constraint (10% of DRL)
DARLINGTON	3,514	0.3	1,171,171	117,117	0.36	0.3	121	12
PICKERING	15,405	0.800	1,925,676	192,568	1.59	0.800	199	20
BRUCE	24,324	1.000	2,432,433	243,243	2.51	1.000	251	25
POINT LEPREAU	4,595	0.040	11,486,488	1,148,649	0.48	0.040	1,188	119

- As may be seen, the HTO emissions are far below the DRLs calculated
- In addition, it has been found that NPP measured emissions are consistently below estimated emissions based on calculation by a factor of 2.5 - 3

- Routine releases of tritium are not expected, nor are they desirable, for fusion operations
- Monitoring for tritium releases and comparing to DRLs are one way for fusion plant operators to demonstrate to the regulator and the public that their operations are safe and have *de minimis* impact on the environment
- The methodology is transparent and defensible
- The approach is customized to each location through the use of site-specific values
- Easy to update when site-specific values, or dose conversion factors, change
- The methodology may be used alongside Agreement State regulations, or 10 CFR 20 Appendix B, Table II Effluent Concentrations