Reviewer 1

Questions and comments

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1 -

Q : « The Cyclus fuel cycle simulator seeks to separate the design of the simulation from the fuel cycle or technologies of interest. »

=> Is that mean that the goal is to build a general environment that can be applied for each cycle/technology ? Quality of results are then not dependent of CYCLUS environment but only depends on quality of cycle/rector data…?

That is correct. One of the primary goals of Cyclus is to separate the concerns of the simulation environment from the specific fuel cycle or process being modeled. Further, it allows for the separation and modularization of the individual processes involved (e.g.., allowing one to model a fuel cycle with different reprocessing techniques by simply changing the reprocessing module). A related sentence has been added to the introductory text. For more discussion, see

K. D. Huff, M. J. Gidden, R. W. Carlsen, R. R. Flanagan, M. B. McGarry, A. C. Opotowsky, E. A. Schneider, A. M. Scopatz, P. P. H. Wilson, Fundamental concepts in the cyclus fuel cycle simulator framework and modeling ecosystem, Nuclear Technology.

2 -

Q In the part 2.3.2 Preferences

How is managed the Socio-economic models..? What are hypothesis?

This paper provides the framework and architecture that allow social models to be used in Cyclus via a minimum cost social-planner framework, similar to other systems analysis models (e.g., Integrated Assessment Models). In this context, it can be considered a “Dynamic Recursive” model. However, the model’s parameterization is determined by the user (via input files) and by future developers by developing modules that interact with the DRE.

Asked Modifications

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1 -

Introduction

« Used fuel can then be stored for a period of time before either being interred indefinitely or being utilized in a advanced fuel cycle by recycling its fissile and fertile isotopes. »

=> I don't really appreciate the term « indefinitely » since it is known that migration of radionuclides could induce a release at the earth surface, even if it is after a very long migration. To my point of view, « disposal » seems more suitable.

Addressed in the updated text.

2 -

« NFC simulation is performed by a variety of actors, including governments, 15 universities, and international governance organizations. »
=> You could also add « consulting agency » since the reference [2] is related on DANESS which is a code developed by the nuclear energy consultant agency « Nuclear 21 ».

Addressed in the updated text.

3 -

In the part 2.1 : « How it is fueled is a result both of fuel availability and associated preferences »

I have a comment related to this sentence. Usually, the fuel choice is decided in advance from industrial consideration more than fuel availability at the time it is needed. Indeed, manage a partial MOX fuel is not the same than manage an UOX reactor. This could change in the future but this is not really sure. Maybe this could be precised in the paper.

Addressed in the updated text.

4 -

2.4 The Nuclear Fuel Cycle Transportation Problem
« and a MILP formulation is provided provided. »
=> Two « provided »

Addressed in the updated text.

Reviewer 2

In addition, I have one more substantive comment, but having not researched extensively in this specific methodology, I was unable to answer; How much of Section 2 in your paper is general theory, compared with new work developed for the purposes of Cyclus and your work in this specific paper?

Specific comments are as follows:
- Abstract: Change to "Past efforts in the U.S. have generally been....."
Addressed in the updated text.

- Page 3, line 3: change to "...supply chain of uranium and thorium ore based fuels, recycled materials (such as reprocessed uranium and plutonium), as well as recycling of fuel....". This is a minor alteration to reflect the variety of fuel forms that need to be considered. As the paper currently reads, it suggests on U and Th fuels.
Addressed in the updated text.

- Page 3, lines 5 & 6: "vintage" has nothing to do with the enrichment level. Please change to something more along the lines of "...and the appropriate cycle length and fuel management scheme that meets the utility's needs e.g., 12 or 18 month refueling outages".
Addressed in the updated text.

- Page 3, line 14: add "national laboratories" to the list as world wide, these are the main developers and users of fuel cycle modeling tools.
Addressed in the updated text.

- Page 3, around line 19: Add the UK National Nuclear Laboratory "ORION" code as this has been getting a lot of publications presented recently. Also I would recommend the journal by N. Brown et al "Identification of fuel cycle simulator functionalities for analysis of transition to a new fuel cycle"
Addressed in the updated text.

- Page 32, line 559: I would have recommended and prefer to see "Total Pu" rather than "Pu-239" as the metric plotted because Pu239 is being fissioned during the cycle, and hence "destroyed" between time steps when in the reactor. The "real world" metric is total Pu as this is something that can be measured.
All figures/text updated to report total Pu rather than 239.

- Page 32, line 564: I infer here that the refueling is either all-UOX or all-MOX, and not a mix of UOX and MOX in a given refueling? In reality, all MOX reactors are partially refueled with MOX

and UOX for each outage. For modeling and to demonstrate your point here your assumption is OK, but I would recommend you point out this assumption.
Added a clarifying sentence: For simplicity of demonstration, reactors are assumed to refuel completely with a single commodity rather than a combination of fuel types as is done in practice.

- Page 32: General observation is that it would be very beneficial in your analysis to have tracked "fuel in pools" undergoing cooling, as a separate mass balance area. This is useful as it differentiates the fuel in the reactor from that "elsewhere" on the reactor site, plus it allows decay to be more easily applied.
I agree that this would be beneficial. At present this is not a feature of the reactor module in Cycamore, though there is current effort to provide a more detailed representation of fuel storage.

- Page 32: On a number of occasions here and elsewhere in the graph plotting sections that follow, you refer to (for example), t=tf etc. It would be easier for the reader if these key time points that drive the scenario are also marked on the plots.
Arrows have been added to each of the close-up graphs to explicitly show time points of interest.

- Page 32: In this section you show the scenario, but make no comment as to the impact it would have on the actual operating facilities e.g., one cannot simply just increase reprocessing throughput by a factor of 2, and same for fuel fabrication i.e. your scenario also has a demand impact and hence throughput impact on the facilities. Please comment.
Thank you for this observation, I completely agree. Because the primary focus of this paper is to demonstrate the capabilities and novelties of the DRE, not necessarily the realism of the facilities in the simulation, I have chosen to add the following sentence to the Experimentation and Results section: Importantly, neither the Separations or Fabrication facilities have throughput constraints, i.e., both facilities are immediately able to process any quantity of fuel.

- Page 34, line 598: In fact the Megatons to Megawatts (MT2MW) program would impact the scenario in a more subtle but important way. For the MOX scenario you describe, and also in the case of the MOX Fuel Fab facility, it is indeed the total facility throughput that is impacted as it is finished fuel that is the commodity being traded/replaced. In the case of the MT2MW program, it is the U ore, and the enrichment components that are impacted, but not the fuel fabrication as that facility remains as the source of the finished fuel.
A clarifying sentence has been added addressing this subtlety.

- Page 34, line 600: Should that read Figure 8?
Corrected

- Page 37, line 635: Should read "All reactor deployment as shown in Figure 5 occurs in Region A"

The authors respectfully disagree and find the suggested text change to be more cumbersome than the existing text.

- Page 40, Section 3.4: Worth highlighting and underlining for the reader that the amount of electricity generated in each scenario is the same. This isn't always the case in fuel cycle scenario analyses, and so often is not a like for like comparison. But your work is.
A clarifying sentence has been added at the beginning of the section: In each scenario, the total amount of electricity generated is identical in order to compare the mechanics and results of fuel supply and demand.

- Page 46, Conclusions. I would recommend and would like to see some indication of the overall run times for these scenarios using Cyclus not only for this work, but estimates for more complex scenarios. It wasn't totally clear what Table 6 run times were showing - was that total run time, or only for each stage of the optimization? Please clarify and address the overall run times and more complex run time questions.
A clarifying note in the table caption has been added regarding total run time. Additionally, a run 5-times the size of the scenarios presented here was also run and reported at the end of the Experiment section. While this scenario is substantially larger, it may not be considered “more complex” by some measures. A substantially more complex scenario will require a great deal of additional commentary to define and justify the details of that scenario, and we feel it will distract from the flow of the manuscript.