Nate Hagens (00:00:00):

Please welcome Iñigo Capellán Pérez to The Great Simplification. Iñigo is an industrial engineer currently doing research at the Group of Energy Economy and Systems Dynamics at the University of Valladolid in Valladolid, Spain. He holds a master's in electric energy and sustainable development as well as a PhD in economics. I have met with him and his team who are working on systems integration of energy, climate, renewable energy, fossil fuel depletion and technical and social transformations towards sustainability. We talked about EROI and the importance of a wide boundary perspective on biophysical analysis. I hope you enjoy this conversation with Iñigo Capellán Pérez.

(00:01:05):

Iñigo, good to see you.

Iñigo Capellán Pérez (00:01:07):

Hello.

Nate Hagens (00:01:10):

Welcome to The Great Simplification Podcast. The last time I saw you was in Valladolid when we had a one-day seminar on biophysical economics at your university six years ago or something.

Iñigo Capellán Pérez (00:01:25):

Yes, pre-COVID for sure.

Nate Hagens (00:01:28):

Yeah. It's interesting, I don't know why this is, and it might be a small sample size, but of the really biophysically aware humans, it seems like 1 in 10 of them live in Spain. Do you have any idea why that might be?

Iñigo Capellán Pérez (00:01:43):

I don't know. Maybe because you are more familiar with Spanish people maybe and then you one person than it's easy to know the rest of us, I don't know.

Nate Hagens (00:01:56):

It could be. So I think this is your very first podcast and I invited you because we met, but because EROI, Energy Return on Investment is what I wrote my PhD thesis on and there's a lot of BS and ideology in today's EROI analysis and your paper, which we're going to talk about, is probably one of the best, clearest, in my opinion, most accurate bird's eye views of this situation. So I really want you to explain a little bit about that. But before we get to that, could you introduce yourself, what is your work, what are you generally working on and how did you arrive at this place in your life and your career?

Iñigo Capellán Pérez (00:02:50):

Now I am a postdoctoral researcher at the University of Valladolid in a research group called Group of Energy, Economy and Systems Dynamics of the University. And what we are basically doing, because we work really in team experience, team work, what we are doing is to try to build system dynamics models that cover all the relevant dimensions in the interface between let's say natural and human systems. So these type of models, they have a name in the literature they are called integrated assessment models. But I can say that we are trying to do modeling, which is let's say quite different from a standard IPCC integrated assessment model. So we are trying to address some of the limitations that this model has. One of the main objectives is to bring more biophysical realities because we think that they are not so biophysically grounded. So the conclusions they extract, they are not so reliable.

Nate Hagens (00:03:59):

Well, that's been my experience too, is the climate modelers themselves are doing the best job they can with a very complex situation, which is the global climate. But then we add energy, energy systems, money, the economy, individual and aggregate human behavior, geopolitics and it becomes really complex really fast. But at a first order, I think to have the climate scenarios better tethered to our energy reality is a first step.

Iñigo Capellán Pérez (00:04:44):

Well, I think here there are several problems, with the existing, let's say more classical models. There are some things that maybe are scientific, other things that are maybe related with the scientific paradigm that we have. So there is a scientific paradigm and then even if you have dozens or hundreds of integrated assessment models, you notice that many of them have the same founding hypothesis. So you have a false

sense of diversity in this sense. And then also you have the problem or the issue that the IPCC, sorry, the integrated assessment models from the IPCC, we don't have to forget the IPCC is a United Nation process. So it is embedded in current institutions. We have the governments there and there are research, there is the research that has shown hope this government has influenced the scientific outcomes because the IPCC reports are not purely scientific outcomes. So it's a mix of them. I can maybe enter into detail of some of the most important things.

Nate Hagens (00:05:55):

So what you're saying is there's two challenges. One is there's group think in the integrated assessment models themselves because they all rely on standard assumptions. And two is there's a political ceiling on what might be said and understood, which I think applies to a lot of the things in the current human predicament, is that correct?

Iñigo Capellán Pérez (00:06:20):

So yeah, I'm going to give a couple of examples not to remain so abstract. From the point of view of the scientific or general paradigm, the current general paradigm is that energy is very abundant in the world. I'm not now referring to specifically fossils or renewables. Both of them are very abundant. We had this debate some years ago with the peak oil and now that maybe especially in Europe where I am more familiar with the politics, now climate policies are being taken seriously. Well, climate problem. So peak oil issue is a bit less important because we want to get rid of it anyway. But for renewables, we have the same thing. So we always see this figure of one square in the Sahara that is enough to power all the world, and which gives the impression that we have a lot of affordable energy.

(00:07:23):

So this is one scientific paradigm which has not so much interference I will say with this institutional framework, but I'm going to give an example where the institutional framework is key. And for anybody familiar with the IPCC scenarios, IPCC framework, we all know that the GDP per capita in the IPCC scenarios is a exogenous assumption. So the models need to be built, designed in a way that GDP per capita, let's say is given and then the models reply the question, what is the energy mix configuration I need to have to be able to grow at this rate, and so on. For example, we build models in which GDP's endogenous, which is what happens in reality, the GDPs, the addition

of all the consumption of goods and services, blah, blah, blah. So it's endogenous in reality, but because of an institutional framework for which growth is not negotiable because even if they have several scenarios in all of them, the GDP per capita grows in all the regions. So it's again a false, let's say diversity.

Nate Hagens (00:08:40):

So they're building the house, which is the integrated assessment model from the roof instead of from the floor foundation?

Iñigo Capellán Pérez (00:08:52):

In some sense, yes, they are fitting the requests from the institution who wants to use that. So it's true that in the last IPCC report, especially the mitigation report, the framework and how it is explained and the topics they cover has changed a lot. I can also feel that there is a generational, I don't know in English, relief and generational shift with more young people interested about more, I will say modern topics, but still the classical IPCC, the classical integrated assessment models are there. These are models very complex. You need decades to build them. So it's difficult to let's say from one day to the other change them or there is enormous inertia in this scientific process.

Nate Hagens (00:09:49):

So my understanding is that in the integrated assessment models, there is not a single scenario that has economic growth declining from here until 2100. There are one or two scenarios where growth peaks in 2070 in 45 years from now and then declines into 2100. But still all of it is growth, net growth from here to 2100. What would happen if the United Nations IPCC or any global governing body produced research that showed declining GDP, wouldn't that be so politically huge of a line to cross? Because then the question becomes, oh, if that's going to happen then maybe energy security becomes more important than low carbon progress. What are your thoughts on that Iñigo?

Iñigo Capellán Pérez (00:10:53):

Well, this declining in GDP will happen because of two different things. It could be the reflection of a recession, let's say a catastrophe or a crisis scenario. And for example, our models typically are able to produce these in baseline business as usual scenarios

in which there are no strong actions to try to avoid the ecological collapse. Then you get this recession scenarios. So this will be one option and the other one will be to have a reduction in GDP because there is implemented an idea of post growth or the growth scenario in the sense, as I understand it, in the sense of a plan reduction of the size of the economy to reduce the environmental footprints, but trying to maintain or even increase wellbeing. So I think on the one hand, politicians in general want to show that they have the control of the situation.

(00:12:09):

So maybe they will not be willing to show these recession scenarios because then people will be afraid. And then if they are afraid they will do things that they will be less controllable. I think this is one part of the story. Another part of the story could be that it is also I think that the mainstream is dominated by the way of giving growth. So this last week was the conference Beyond Growth I think is the official name in the EU in Brussels. I don't know if the news went to the other side of the ocean, but-

Nate Hagens (00:12:45):

I watched several of the presentations.

Iñigo Capellán Pérez (00:12:49):

Okay, so this is not the first conference about this. There was at least one more. I was present, I don't remember now the year, but this year it seems it's bigger. There was the president of the commission von der Layen and in the opening and it's very interesting that there were several high rank staff from the EU commission in the Beyond Growth Conference saying that we need more green growth. So I think this is very paradigmatic. I think also this, the growth, post growth ideas are very and not known, not well known in the mainstream. And also they are very easily misrepresented and they don't distinguish sometimes the growth and recession. So I think there is a lack of awareness of these ideas in the policy arena.

Nate Hagens (00:13:42):

Your papers clearly imply that a de-growth scenario is going to happen from your first scenario because of energy and biophysical limits, not a political choice. And I'd like to get to the one paper that I'm referring to, but maybe as a biophysical analyst you could first explain because I don't think I've actually had a guest, you're going to be my 80th episode, I haven't had anyone that's specifically talked about energy return

on investment and how important it is or how not important it is. Could you just explain to a layperson that isn't aware of this, what is EROI? Why is it important? How has it been an important indicator for the prosperity of societies and as it declines what it will imply for societies?

Iñigo Capellán Pérez (00:14:47):

Okay, yes, I think it's a good idea because this a concept that sometimes it looks a bit abstract for people who are not familiar with it. So yes, basically EROI is the acronym of energy return on energy invested and the name is trying to refer to their return of investment from the financial world. And it is basically a ratio between how much energy do you invest to have an energy system providing you energy back. So here there is that you want to build an energy system that is going to provide you, I don't know, let's say 100 energy units over its lifetime. You should have, I mean to set up and to build and to manufacture and to run and so on, this energy system should require much less than 100 energy units because if not, then you have a net loss.

(00:15:47):

So this, which I think for one energy system is very intuitive. We can extrapolate to the full society because it is true that we know that not all the energies have the same quality. So if we have in the society an energy which are very high quality, which are very high EROI, we can somehow help or allow that other energies with low EROI can enter into the system. I think the classical example for this is biofuels, biofuels have a energy return on energy investment, which they are between one, two, three, of course it depends on climate, it depends on agriculture management practices, but very, very low EROI. This is not scalable to replace for example oil, it will reduce a lot of the EROI of the society.

(00:16:45):

So the EROI is basically an indicator of efficiency also. And why is this important? Because basically the current society, there is uncertainty in the estimates because it's very difficult to calculate at societal level. But basically we need between five and 15 EROI standard in let's say industrial modern societies as in USA or Europe. So we need to be able to get for each energy investment at least five or 15 units back. What happens if this EROI reduces? It's important here to have in mind that there is not a hard limit for EROI because there was also a debate about which is the minimum EROI to sustain our society. So my understanding and our understanding in the group

together with Professor Carlos de Castro, which by the way I forgot to mention because all the EROI work we do together in the group. So it's just to mention him also, the EROI here-

Nate Hagens (00:17:55):

I know know Carlos, but your English is much better. So I invited you but please give him my regards.

Iñigo Capellán Pérez (00:18:02):

Thank you. Thank you. I will. So what I was saying, ah yes. So there is not a hard threshold because different societal configurations can work with different EROIs. For example, if we have a system of, I don't know, private transport with no public transport at all, then we are going to spend much more energy on sustaining this network of private transport that if we have a solid private, sorry, public transport. So with less energy we provide the same energy service. So there is never here a hard threshold but of course there are some mechanical limitations which are important. So if the EROI tends to decrease, if we want to maintain the same amount of net energy which corresponds with the consumption of goods and services, food, cooling and heating our houses, producing goods and services in the industry blah, blah, blah, then we will need more primary energy and more because we have more losses.

(00:19:12):

So for the same amount of net energy, we need more primary energy and if we need more primary energy, this needs two things. More environmental impacts, if we are talking about fossil fuels, more emissions in particular, and if we are talking about renewables, this means that we are eating a higher part of the cake of the sustainable potential, which is also one of the topics that we work in our team. That is very important because if we have a sustainable potential for our renewable of 100 units of energy, if the rate decreases a lot then the primary and we are going to need a lot more of it. And if we cannot increase the primary energy, then the amount of discretionary uses for energy, the amount of goods and services that we can enjoy decreases. And this in growth dominated system is recession, in a de-growth plan system we could deal with it.

Nate Hagens (00:20:14):

Thank you. That was clear. So you said that the EROI of society, not of an individual oil or solar or geothermal technology but for society needs to be five to 15. So let's just talk about the five. So if the EROI of society was five, that would mean that if we had 100 units of energy for society or a million or whatever it would be, that 20% of that energy would be used by the refining, discovery, extraction, distribution of energy to the rest of society. Meaning that 80% of our total energy only would be available for hospitals and air travel and shopping centers and universities, is that right?

Iñigo Capellán Pérez (00:21:16):

Yes, the interpretation is correct. The only thing maybe I forgot to mention before is the issue of boundary is because I'm talking about EROI, but EROI we need to specify which boundary. When I mention five to 15 it will be EROI standard, which is the energy return on energy investment at the generation plant. So this does not include transport for example, transport of energy, which is a very relevant part of the cake also.

Nate Hagens (00:21:48):

What does that mean?

Iñigo Capellán Pérez (00:21:49):

If we will take as reference the EROI point of use, then the thresholds reduce, it will not be five, 15 but I don't want to say numbers because I don't have the calculation, but it will be much lower.

Nate Hagens (00:22:05):

It would be three to nine or something like that, who knows?

Iñigo Capellán Pérez (00:22:11):

Yes, we will need to do proper calculation but yes it will be lower. So here I'm talking in EROI standard terms.

Nate Hagens (00:22:20):

Okay, so in the EROI of five, in the standard terms, actually a greater percentage than 20% would be allocated to the energy sector if you include transport and distribution and everything?

Iñigo Capellán Pérez (00:22:37):

Mm-hmm.

Nate Hagens (00:22:39):

This is what I refer to as a Mordor economy, is as we grow our gross energy and our net energy stays flat or declines, it's good for GDP but our entire system ends up being increasingly allocated to the energy and material sector to power the rest of the system and increasingly we'll have to use some energy to mitigate environmental damage from the use of so much energy.

Iñigo Capellán Pérez (00:23:10):

Yes. Can be understood as a loss of efficiency, we are less efficient, we use the resources in a worse manner.

Nate Hagens (00:23:26):

So let me take a side step there and I want to get to your paper, especially a particular graph, but there's efficiency at three levels, and this is, I'm just thinking out loud here. The first is the efficiency of the oil, well, the energy source at its point of extraction, like you invest one barrel of oil and you get out 100 barrels of oil from under the earth. So that process gets more or less efficient over time. Then there's the efficiency of the point of use like driving an electric car instead of internal combustion car or you are more efficient by using electrical energy than waste heat. And then the third would be the human choice efficiency. I drive a big car by myself versus fitting five people into a small car, that has nothing to do with EROI, that has to do with the human choice of what they do with the energy once it's at their car. Does that make sense? And are there models that include all three of those steps?

Iñigo Capellán Pérez (00:24:54):

Well, almost no model includes EROI at all. So the question about the limits it's very broad question. In general, I mean when I mentioned at the beginning that why we are developing a new integrated assessment model when there are already, I don't know, hundreds maybe out there, there are some reasons why. And one of the reasons is that we want to be able to understand what are the implications of a changing EROI in the whole system. Because another of the paradigm thinking is that especially from green growth and from the mainstream is that in general we can do the energy

transition plugging out some sources of energy and plugging in the renewables and let's say that the rest of the system, economy, society, cities, whatever, will remain the same. But our understanding is not, is that the transition is going to imply changes in the society and the economy. So we need to have these feedbacks feeding from the biophysical dimension to the economy. And for that you need to design models from the start, from the core they are thought to take these relationships.

Nate Hagens (00:26:18):

So with that, let's go to your paper, the paper's called Dynamic EROI of the Global Energy System in Future Scenarios of Transition to Renewable Energies. Can you give a brief overview of the paper but specifically explain what the figure nine is attempting to show?

Iñigo Capellán Pérez (00:26:43):

So this paper is the result of a lot of years of work. I will start saying that our idea was because as you have mentioned, the EROI literature and debate is many times many confusing. There are many people doing estimates, obtaining very different numbers. The hypotheses are not always clear. There is this lack of transparency. So we knew it was a world, how to say, especially for us that we never studied before EROI, difficult let's say. So our idea was in a integrated assessment model we built for European project called MEDEAS. So we had different levels of MEDEAS, we have MEDEAS world, MEDEAS EU and then MEDEAS country level. So here we were interested into looking at the problem at the global level because now with the global trade and so on, I don't know, in Spain we are installing a lot of PV but if this PV is manufactured in China but then the energy investment is done in China. So we wanted to have the global picture not to have to deal with this trade effects.

(00:28:09):

And the idea was to see what will happen with the EROI of the system in a dynamic way if we do the transition to renewables at different pace, at different rhythms. So in this figure we have three lines. We have GG corresponds to green growth and the percentage refers to the amount of renewables in the system in the year 2060. So for example, the thick solid line is a green growth scenario which attains 100% renewables in 2060. And the other two scenarios are, let's say less stringent and we wanted to see the difference. So what we see basically here is that if we do this fast transition, which in fact is a transition we should do if we want to avoid climate change, all the time

thinking in green growth perspective, we were interested into assessing the feasibility, technical feasibility of green growth.

(00:29:14):

We were not interested into proposing a workable alternative in this paper. So we saw that the EROI of the system will decrease a lot and very fast. So from the level we were talking before, something between 10 and 15, we will be something in the minimum because there is like a rebound. I will explain now why this rebound three, four.

Nate Hagens (00:29:43):

Just to be clear, this is the standard EROI not the wide boundary. So that, like you said before, things like transportation and the ultimate distribution of the energy is not included in this?

Iñigo Capellán Pérez (00:29:55):

Well yes, here the thing is that we use something in between a standard and point of use, but we are much closer to a standard because we didn't compute all the energy embedded in the grids, which is enormous. So we only took some effects related with the general system. For example, we took into account transmission losses, we took into account everything related with the management of variability. So if we need to put more storage and if we have some curtailment because the system has a very high share of renewables, variables. So it's something in between but I think we're closer to standard.

Nate Hagens (00:30:45):

And you were about to explain what happened in 2055, the rebound, yeah?

Iñigo Capellán Pérez (00:30:51):

Yeah. So the rebound, why this rebound? Because the renewables have a pattern of investment of energy and money very different to the pattern of investment of fossil fuels. In general fossil fuels, you have a investment at the beginning but then you have also significant investment that you need to do all the time to extract this energy. Basically for oil you need to be pumping all the time and to pump this you need energy. But for renewables, the investment, the big investment in terms of energy, money and materials is that at the beginning is up from investment. So you spend a

lot of money, materials and energy, even your plan has not started to provide you one unit of energy. And then in terms of operational maintenance it's much lower. So what does it happen that if you all, you need to do the transition very fast, you need to put all the up front investments now and this is what drags the EROI of the system.

(00:32:00):

And this is the reason it recovers because when you reach 100% you arrive like a stationary state with where you only need to replace the capacities that are being commissioned. So you don't need to expand the system but maintain. And that is the reason that after the minimum it is stabilized, I think it is stabilized at around seven or eight, I'm not sure now in the paper we didn't show because we were focusing on the 2060, but I think we explained in the paper. So we recovered because this paper, our paper has been criticized. Well, first ignored I will say and then by those who didn't ignore it, they criticize and the main critic is in your group you do EROI estimates that are very low and that are bad estimates, are not reliable. But the thing is that we use EROI levels that are within the range of the literature. So the thing is that didn't got the point that we are using a standard EROIs from the literature but we are capturing the dynamic effect because the EROI literature is dominated by static assumptions.

Nate Hagens (00:33:17):

What does that mean dynamic effect?

Iñigo Capellán Pérez (00:33:20):

Dynamic means over time, variation over time. So if you are analyzing a problem related with the energy transition, the energy transition is inherently a dynamic problem because you are increasing the share of some technologies at the expense of other technologies. So there are dynamic effects and what I explained the pattern of investment, you will have the lifetime of 25 years. It is not the same if you need to do the investment in the year one or if you need to do it over the period distributed. So most EROI analysis made by the teams that say are more influential, they use static assumptions and they don't see this dynamic issues because their methodology is not able to see it.

Nate Hagens (00:34:14):

So I have a lot of questions here. This may be esoteric to a lot of listeners, but I see why this is important. This is the whole story. This is building the house from the

foundation. First of all, I forgot to ask you this earlier, why should people use EROI analysis or net energy analysis or biophysical analysis instead of just looking at the market prices and using dollars?

Iñigo Capellán Pérez (00:34:48):

Well, I mean the question will be asked as why is biophysical economics important? The basic idea is that economics understood in a constrained way just looking at dollars, is a very partial and incomplete view of economy. So it's true that it is the dominant way of looking to the economy. But if you go to ecological economics or biophysical economics, there is that in order to have the complete picture you need to have physical dimension also, you need to have kilos, you need to have cubic meter of water, you need to have tons of resources, you need to have Jules of energy because with the money you can do things that are a bit, you can trick a lot, you can give subsidies, you can put taxes, you have inflation, the government can get in debt. But the physical reality is like the foundation.

(00:35:50):

So EROI is opposite. Let's represent the foundation and let's try to capture after what are the impacts in the monetary dimension, which is also important. I don't want to say that it's not important. The economy is very important and in our models is one of the most important modules. As you said before, how we manage the consumption and the production is critical. Is critical and we need also to deal with it. But it's not the only thing we have. Carlos, if he will be here, he will say that these models that only have dollars are flat earth models.

Nate Hagens (00:36:31):

He would also say that Gaia might have something to say about these models.

Iñigo Capellán Pérez (00:36:35):

Yes.

Nate Hagens (00:36:36):

No I'm kidding. So here's another question. I used to love EROI because it made so much sense to me as you just described, but now I think it's often used as an ideological tool to represent fossil fuels favorably or to represent renewables favorably without a lot of standardization. So one of my many pet peeves is EROI stand

standalone for a technology is mildly useful. But what we really need is what you did in this paper, which is an EROI of the system because if you add a little bit of a solar panel, solar photovoltaic to a system, the EROI of it as a standalone is probably accurate. But as you increase it to 10% of the system or 30% or 50% or 80%, the cost to the system with the backup and the transmission and the distribution and all those things reduces the EROI of the system. So can you talk a little bit about the importance of using a system EROI of the entire, I guess it would be a grid in a region or a country or a world.

Iñigo Capellán Pérez (00:37:57):

I really like your question because it goes to the heart of the problem, precisely we wanted to avoid when we were doing this research is to avoid these never ending debates about EROI of solar. The solar is intermittent, I need to assign back up, how much backup up, then there are so many assumptions that as you said, you can get what you want. So where there is, we are not interested into allocating energy cost to any technology, we're interested in to have the complex picture and know what is the energy cost of that energy mix and if I can get a better energy mix, this combination is better.

(00:38:37):

And also, we have to be aware that the energy mix is going, I don't want to say the word optimum, but the best energy mix is going to be different in its region because it's not the same, the sun we have in Spain that the sun they don't have in Denmark. So there are a lot of things with EROI that have not been done properly. So why is important the EROI of the system, in order to have the full picture and to avoid to focus in the trees and to see the forest, I will say.

Nate Hagens (00:39:15):

Well, speaking of the forest, one could argue that in your solid line scenario, the green growth of 100%, you're treating energy as the limiting variable. But if we were to scale renewable energy to be 100% or anything close to that, we would then run into water and mineral and material and land and maybe forest limitations. So EROI focuses on energy as being the most important variable and I would argue that other than the ecosystem services of Gaia, it is the most important. But there are other limiters too. So that would be an additional layer of complexity to your model, right?

Iñigo Capellán Pérez (00:40:09):

Yes. When I give talks about this, I generally start by the general picture, mention the planetary boundary's framework, definitions of sustainability and then one of the elements because we have to distinguish between renewables and sustainable renewables, not all the renewables are exploited in a sustainable way. So as you said, we need to have into consideration a lot of things. And then for the technical feasibility of the system, the EROI is something important but the EROI is not the perfect indicator. Maybe it will be good to insist on this not to give this impression. The EROI captures very interesting characteristics but does not see many others. So yes, renewables, limits to renewables, there are different limits, also different limits depending on the technology. For solar and wind, I will say some materials will pose a problem. For land, I think it depends a lot on the region.

(00:41:25):

So we have done some research about potential land constraints for solar and for example, what we see is that it depends a lot on the country because let's take … for example, it is not the same as Australia with enormous size, I mean very little density, small density of population and a lot of irradiance than, I don't know, UK, UK low irradiance high density population, high energy consumption. So in some northern European countries it could be a problem but of course they are already trying to find a solution through trade. But I don't know, it's a topic which is very broad and yes, the renewables will have different problems.

Nate Hagens (00:42:19):

So back to your graph again, you had real data through 1995 to 2018 or so that the EROI of the system declined from 16 to 12. So can you speculate or did you do the analysis and I think renewables system-wide right now are around 5%, depending if you include hydro or not. But it's already declined 20% in the last 25 years. So what if you didn't have a green growth scenario and you just continued the current mix, will that EROI also continue lower or didn't you do that analysis?

Iñigo Capellán Pérez (00:43:04):

Well the MEDEAS model is not ready for this, I will explain why. This data from 1995 until 2015 or no, 2010 I think in the case of MEDEAS, are derived from historical data basically from the international energy balances. So what the model is capturing there is something that is not new, it's something that has been found in other studies by,

for example Paul Broadway team or there is also a team in France that has published some EROI estimate which are showing that the EROI of fossil fuels over time in the last decades has a declining trend.

(00:43:48):

So I think the EROI data captures this but in MEDEAS, for the sake of simplicity, we did not consider that the EROI of fossil fuels decline over time, which is one of the optimistic assumptions we did in this work. I think we have a full paragraph about the limitations and we took a lot of care that all these limitations will be biased towards overestimating the EROI be because we knew we were going to receive critics. So for us the EROI of oil in 2050 and 2060 is the same. So this is a wrong assumption but it was very difficult for us to project that and we decided we already had interesting results without it and we kept it like this.

Nate Hagens (00:44:41):

As a human, you're a scientist and a human, but as a human, when you saw these graphs when they first came out of your computer and it showed that the EROI, which you just said is probably a little overestimate from reality, got down to three in 2055 before rebounding, what was your reaction? I mean I can't imagine our society could function at an EROI of three, not remotely how it looks today.

Iñigo Capellán Pérez (00:45:14):

Well I think as a human, I first thought there was some error because I mean to our knowledge, no one has done this type of research, so you are blind. So I don't know, my intuition or my bias was telling me that it was not going to be so strong. So you'll try to find errors, you always find some errors, but in this case I remember they were not relevant because many times you find two errors or they compensate one with the other, especially when the model is already very validated. And then the second thing I think, and this is how I interpret this, is that the green growth story for the whole world is this, is a story they they're telling us.

Nate Hagens (00:46:05):

Do you think they're lying or trying to trick or do some political thing or do you think they're energy blind, they just don't understand the biophysical ground up?

Iñigo Capellán Pérez (00:46:27):

I think it's ignorance, I think, my opinion, maybe I cannot talk for 100% of people. But for the most I think it's ignorance. There is a status quo, a mainstream scientific paradigm and it's one of us saying this against 10 other saying other things.

Nate Hagens (00:46:44):

10 other well funded and supported people by the way. So what would be, I assume the objective of your group at Valladolid would be to integrate graphs like this and the numbers that support them into the integrated assessment models to have more accurate portrayals of net-zero and some of these scenarios that are very popular, yes?

Iñigo Capellán Pérez (00:47:17):

Well, that will be one option. Our group is really small, so it's like it's an enormous task for one group. I think we should maybe devote more time for this type of strategies. But here we have to talk about how science is financed because our group is a very reduced number of professors, most of us, our contracts are attached to projects. So if the European commission or the Spanish ministry is not interested about EROI, we don't get project about EROI. So we do this on the side or we try to do it as a sub-task of a big project. So what I want to say is that we have a small capacities in the group to do this type of, how to say, to be influencers to say in modern terminology.

Nate Hagens (00:48:17):

So do you think the Ukraine, Russia situation has accelerated interest in this realistic energy future scenarios?

Iñigo Capellán Pérez (00:48:29):

No, I don't. No, I think the European Union had a green deal package with a lot of investments for the transition and I think this has distracted because of you cannot have many main goals. So this has distracted the attention. I don't know, to some point I imagine also the budget because all the military budget is now skyrocketing. So where is this money? If we spend on this, we will not spend on other things. And what is maybe is it has accelerated all the issue of hydrogen in Europe. Because as you know, the problem with Russia, Russia is that we were consume, well, no problem, the situation it was that Europe was very dependent on Russia natural gas, not only natural gas, metals, nickel, also fertilizer, et cetera, but natural gas is a bit the most

famous. So now there is this idea which was already on the table, but now I think they are trying to boost it.

(00:49:36):

So the south of Europe and the north of Africa, Morocco and so on, produce with a lot of renewables, produce hydrogen that is then transferred to the north of Europe, synthetic wells or whatever to replace gas. So this is another research challenge which in the research team some of us are very motivated to analyze. There is almost no EROI on hydrogen fuels and so on. It's a blind spot and they are put in the European Union, millions and millions of euros on something that in our opinion is quite immaterial.

(00:50:14):

This reminds me a bit of biofuel story, when the issue of peak oil started to be a bit relevant, then they started to invest a lot of money in biofuels. Few people were warning take care, this doesn't make sense. And then they realized because this is one of maybe personally I find a bit frustrating, that for me science about environmental problem is about anticipating. So with this simulation models, you detect some issues that now are not a problem, but that could be a problem in the future. You anticipate, you foresee them and then you tell people take care, if you continue like this you will face this problem. But the problem is that we say things and they don't listen and then they only realized that this is a problem where they have already made the mistake. So it's a bit useless, with biofuels is the same.

Nate Hagens (00:51:12):

Yeah, I agree with you. Actually my only article ever in science was about corn ethanol like 20 years ago. On that note Iñigo, are you afraid of science and the scientific process as we approach tougher economic times that the actual science about scenarios, realistic scenarios about the future politically within the peer review and institutional funding process will start to be different? Do you have any fears about that?

Iñigo Capellán Pérez (00:51:57):

I'm not so pessimistic in the sense that I don't think personally that this is totally now subjective opinion. We have enormous challenges. There are some people who think that we are doomed to cows or to really bad, bad times. I'm not so pessimistic. I think

this comes also with your character, but I have, if I can bring some rational elements, if you look to the history, the history is full of events with situations very, very bad for people, very bad times that they manage to overcome it. Of course also there is plenty of situation where they did not manage to overcome and it was very bad. But this is my opinion, that the humans we are, if you are aware of the problem and you are motivated and you understand and you have a sense that you can achieve, we have an enormous energy to mobilize.

(00:53:01):

And as we say, the EROI's determined by social decision and economic decision. Nothing is written in stone. So I don't know, in this sense I'm not so pessimistic, but I'm aware that we need a change, a radical change. In this sense in terms of energy, another strand of research which I have is related with energy communities, energy comparatives and these type of projects, even if they are small for the moment, they don't have most countries an impact in the macro view. These projects give hope. They are examples of what can be done and I think they are like seeds of change.

Nate Hagens (00:53:49):

What does that mean energy communities?

Iñigo Capellán Pérez (00:53:52):

Okay, I think it's maybe more a term in the legislation, but basically is there that historically the energy has been supplied and managed by very large companies, private companies or state companies, it's the same. It's something outside of the control of the citizen. So all these also they call energy democracy or energy cooperatives. Energy communities is there that people, lay people you can make an association for, I don't know, for getting your food locally and sustainable. You can also make an association to install some PV panel somewhere and then share this energy, so this is the idea.

Nate Hagens (00:54:38):

So it decentralization you're talking about kind of?

Iñigo Capellán Pérez (00:54:42):

Decentralization but also decentralization in the ownership and the management of the resource. Because if you can have decentralization for a technical point of view, if all the panels are on or everything is controlled by big, large corporations.

Nate Hagens (00:54:59):

Yeah. Excellent. Well this has been a helpful glimpse into a biophysically plausible green growth scenario. If you don't mind, I would like to ask you some personal questions. Since I've known you for six or seven years, you have thought about EROI, biophysical economics, peak oil, climate change, these things, as an individual and as a career choice, do you have any personal advice to people watching or listening to this at this time of global meta crisis?

Iñigo Capellán Pérez (00:55:39):

It's difficult because this is so far from our daily life, especially in Europe-

Nate Hagens (00:55:43):

I know, you're a scientist.

Iñigo Capellán Pérez (00:55:44):

... and let's say rich countries, so it's totally disconnected. So for lay people who are not interested about this or have no information, the message is hard because the message is the life we have now is temporal. It is not sustainable. Maybe if you are young, 30, 40 years, you will see these problems, your family will see. So that will be maybe my message that don't give for granted what you have. This is sustain, we say in Spanish, it's a giant with mud feet, I don't know if in English you have such a-

Nate Hagens (00:56:37):

Cómo se dice en Espanole.

Iñigo Capellán Pérez (00:56:37):

Un gigante con pies de barro. A giant with mud feet. So it's looks-

Nate Hagens (00:56:37):

Mud feet, okay.

Iñigo Capellán Pérez (00:56:40):

... normal, but it's very unstable.

Nate Hagens (00:56:44):

Yeah. Well I agree with you. So you teach at a university, you're a postdoc. What recommendations do you give to 18, 19, 20 year old humans at Valladolid University or any young people listening to this program?

Iñigo Capellán Pérez (00:57:01):

I will say that everybody should, when we make plans for the future, big things. For example, buying a house or I don't know, these type of things. You need to carefully think if this is really going to be a good option in this context. So to try to be more resilient. Also, I think there are two things here. There is a structural change and there is the personal change. I think I'm not naive to think that if everybody change our behavior, then the world will be perfect. This is totally naive, but it's true that this is one of the pillars of the transition. So I think we have a process, especially in rich countries where we are surrounded by this super abundance and over consumption and so on, that we need to learn to live ourself with less. We have, I insist a structural constant, but as a way to be good with ourselves, I will say. So if in the future there is some bad situation, we are ready and understand what happens and know and be used to that.

Nate Hagens (00:58:15):

What do you care most about in the world Iñigo?

Iñigo Capellán Pérez (00:58:18):

I think values. Values of I think freedom and autonomy. So if people are really free and autonomous in the way that they are not manipulated, think that can save us from many things.

Nate Hagens (00:58:35):

And of all the issues in the world could be biophysical analysis or anything else, what issue are you personally most concerned about in the coming 10 years or so?

Iñigo Capellán Pérez (00:58:46):

I think my main worry is that all these problems will be too much and it will be a big mess.

Nate Hagens (00:58:54):

And in contrast to that, what gives you optimism? What things have you witnessed or small examples give you optimism and some inspiration for a better future than the default?

Iñigo Capellán Pérez (00:59:08):

Examples that are happening now, I will like to highlight this group of people who gather together in a small comparative for providing themselves not only with energy, but bio food, finance. Even we have now in the city a cooperative for transport with electric cars which are shared. I think this gathering, doing projects in common is very good. And then in the history, for example, I really always recommend the book from Jared Diamond on Collapse, which is a classic now, which gives these examples of societies which fail and societies which survive. So I think there is a list of historical cases. There is the case of Iceland, there is the case of Japan, which managed to survive. It's true that in some cases without authoritarian rule, this is maybe not optimal, but there are situations.

Nate Hagens (01:00:16):

If you could wave a magic wand with no personal recourse to you or your reputation, what is one thing you might do to improve human and planetary futures?

Iñigo Capellán Pérez (01:00:29):

Well, I think I will maybe repeat, but I think for me it's very important, this idea that everybody, we try to be or we are non-manipulative, that we transparently see when someone is cheating on us, someone or the system, that will be magic. Like a red light in your brain when someone is trying or a situation is not true and they're manipulating you. That will be like a semaphore very useful.

Nate Hagens (01:00:59):

Full behavioral transparency. Excellent. This has been great Iñigo. As usual, when I have my first guest the first time on the program, I'll ask you, if you were to come back in six months or nine months, what is one topic that maybe we didn't cover today that

you are very passionate about, interested in, that is relevant to our future that maybe you could come back and do a deep dive on that topic?

Iñigo Capellán Pérez (01:01:30):

I will say that two things for me are very key. One thing will be all this net energy assessment of the hydrogen. And the other thing will be what are the sustainable potentials of renewables or to try to understand a bit more the situation.

Nate Hagens (01:01:50):

Do you think that a group of researchers either at Valladolid or 10 other universities, if they very convincingly came up with research and analysis showing that the net energy of hydrogen system-wide was a bad path to go on, do you think that politicians and decision makers would actually heed that advice or is the momentum too strong to change that?

Iñigo Capellán Pérez (01:02:22):

The problem I think are delays because we have not even started. So that means that we will get results not before two years. In two years the amount of investments done is going to be a enormous and this year are going to be for me like stranded assets. And this is what happened with biofuels. Now we are consuming in Europe biofuels because we built some refineries 20 years ago and these refineries have a lifetime of, I'm not sure how many years, but we need to use them until the end. So maybe there is a risk that again, we arrive late and then they cannot undo what they did. Also, not to acknowledge that they did an error. Because for example, about hydrogen, I can give an anecdote. A couple of weeks ago I was in a debate about hydrogen with some people who are working with hydrogen and well, they call me a bit to be the opposite side of these people who are working with hydrogen and think that it cannot be applied in many things and let's say more the most typical view.

(01:03:32):

So the debate was very good. I think it was constructive and we were listening to each other and I think it was very respectful and so on. But at the end how the debate finished, there was an intervention from one person from the research center who said, anyway, the European Union is putting a lot of money in, so there's going to be a lot of job and money there. So when the debate finishes like this, then I can' go out

because I mean we have different priorities and we have different ways of taking decision.

Nate Hagens (01:04:09):

Well, I wish you luck in your work on that. I do think more broadly we need massively more education on how important energy is to our lives, how our fossil energy is depleting, it won't be here forever. And the importance of energy quality and energy properties that not all jewels are created equal. And we can't just create these hydrogen cars and scale renewables and continue to power a 19 terawatt society. We are energy blind and thank you and your team at Valladolid University, at least trying to build the analysis from the ground up. I'm a big fan of your work Iñigo.

Iñigo Capellán Pérez (01:04:54):

Thank you very much Nate, for your words and we welcome everybody interested in this type of research in our group. We will be very great to host anybody for short time or long time.

Nate Hagens (01:05:08):

To be continued. Saludos amigo.

Iñigo Capellán Pérez (01:05:11):

It was a pleasure to be in the podcast, was very, very fine. So thank you again and see you soon.

Nate Hagens (01:05:21):

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