**RQ1**

**1.1What is your current role?**

P1:

Okay. So my business title is CTO of the TIBCO Spotfire’s Development Team. I overlook technical, I mean, road maps and stuff we do and so on. But at the same time, I also doing active software development in my role as well.

P2:

now I'm I'm a data analysis at work for a Tik-Tok.

P3:

I'm a master student, but before I had been working in the software, in a software company at about three years. My bachelor degree was a software engineering and after that, I'm being, I had been working for almost three years.

P4:

So I'm a technical director at spot Fire, um, so I work with the technical strategy and going forward, a lot with our different teams around the way we develop, as on the process around software involvement and and the tools that we use. So I had been a software developer myself for ten years I don't do sort of hands on coding myself right now, but I'm still very much involved in the software development.

P5:

So I work as a software developer at Amazon Japan. I'm a software development engineer too, so not a new graduate role, but slightly experienced.

P6:

I’m the graduate school master student. I have studied the math, game theory, python, c++ for 4 years in the bachelor program.

P7:

So I'm, my current role is a senior software engineer, so in most cases, just service development and service planning. In in terms of, like, technology and architecture, uh, which also includes some load testing and capacity testing. It's kind of relevant to, like, your question about the, um, number of servers and so on, um

P8:

The official researcher.

P9:

Okay, are My current job is, I'm a Phd student in Machine Learning.

P10:

Software engineer, responsible for the development of network operation and maintenance management tools.

**1.2 How much experience do you have in software development?**

P1:

So, and I've been in software, I see the question there. So I've been in software development for, let me see, 25 years or so. I used to be a hardware engineer to start with, but I moved over to software.

P2:

I have done some web pages and and mobile software. many years ago. And, I have about five years experience to develop the some softwares or some pages.

P3:

5 years

P4:

20 years plus

P5:

So I've been working as a software developer professionally for around three and a half years, But, um, I've been developing apps, software and etc..For about since my bachelors, that is around five years plus, so around five years. I have experience in software development.

P6:

I have experience in HTML, JavaScript for one year and a half, and I am now still studying the web development.

P7:

I think seven years now.

P8:

I joined five or six development in the past, so maybe not. Yeah, I have, I have many, I think, experience.

P9:

I have some experience and develop the algorithms for developing some theoretical analysis, or maybe some algorithm design, and I will write some codes. But for developing the software. I not have a very comprehensive experience.

P10:

3 years experience of AI research and one year of industry software development.

**1.3 What do you know about the carbon footprint of software or the impact that software has on the environment?**

**& 1.4 What do you know about the energy consumption of software?**

P1:

I mean, what I think, I mean, the natural thought, when you talk about carbon foot print, uh, it's actually a bit coin mining, which I think is horrible because it do require so much energy..Uh, but otherwise, I don't think that we, in our products are discussing this at all. <Products are not considering> But, I mean, it's normally not the carbon footprint is more like thinking about, I mean, primarily is to reduce the power consumption. I mean, meaning that you don't execute your software more than necessary to perform some task.<Not necessary> Uh, but that's more for from a primarily, it's more from a the the angle of our customers don't shouldn't be forced to pay for more energy than necessary. But I would say that we we not spending a lot of thought in this area to today. That it’s the honest answer.

As I mean, carbon footprint is not always directly, I mean to the energy, its energy consumption. I mean, it depends on where where the energy comes from.<Source of energy> If the energy is, I mean, carbon neutral, then in that case, the common footprint is still small, even if you consume lots of energy.<carbon neutral> Of course. I mean, I would say that at least most of our customers are not in Sweden, but the most our development is in Sweden.<location of customers> And I would say, majority of the energy in Sweden is not a carbon. I mean based, I mean there are some, but most of it is, I mean, water, wind, nuclear, power and so on.<type of energy majority>

P2:

To be honest, I don't know a lot about the carbon footprint of software, <do not know too much>but, the development, maintenance or use of software will make us electricity of computer, <maintenance or use of software use electricity>or some part of electricity produced by burning carbon, which can generate carbon dioxide and pollute the environment.

I think you know, maybe it's a huge power consumption industry and has a carbon footprint on something. And when we do some research, or we um look through some web pages, it will produce a lot of on carbon dioxide into the environment, and it may be have a bad influence for the environment.

P3:

Oh, as far as I know, um, I think sometimes when coding or when just compiling the software, it could introduce some carbon foodprint, carbon foodprint, footprint waste<compile codes>..Because sometimes when you compiling the code or doing something is kind of useless, and you can just not do that. And maybe after you prepare a well, and then you can do it again.

Oh, I think maybe when you coding and when you compeling the software, and also when you doing some tests, especially for the continuing integration test, it could because more energy can something..And also, I think, you know, before, I was a software engineer in a television products production company. So almost everyday we need to keep the software a running,<keep software running everyday> and also to test some trains or or to test the futures of the television. So I think this is also a kind of energy consumption, OK?

P4:

that's not something that I think about, in our sort of daily job.<not think and discuss> The the only thing I can think about is, sort of, the all the things that we store on on service, in the cloud, of course, those computers, uh, need electricity<need electricity>. There's been a lot of talk about, you know, mining crypto currency, e.g., instead of that. It, uh, it's not a sustainable way of of handling money in that sense. Um, so, yeah, but it still feels like an area, and that we're not discussing that much.

P5:

Um, to be honest, I don't know much. <do not know much>Um, I do know that the service that we deploy, the code that we write to reach the customers, it has to run on dedicated service data centers. And they consume a lot of energy. More energy consumption more. Of course, it releases a lot of heat. I'm not sure about radiation.<service data centers> Yeah, heat is, of course, and that causes, UM, that is basically carbon footprint rate. It consumes energy, it produces heat, it takes up resources. So, yeah,

P6:

I never care about the carbon footprint, I just know the concept of the carbon footprint<not think about too much>. Okay, the carbon footprint is that carbon dioxide emission all from the process of the making products and the indicator converts the carbon dioxide emissions. I have never heard about the carbon footprint of the software and the internet.<never care about carbon footprint of software>

P7:

UM, that's a good question, because it's something that I usually do not think about too much<not think about too much>, like, definitely, when I try to write some code, or, like, trying to implement a service, I do think about the performance to make sure that we can achieve our requirements with a minimal amount of servers that we need, which I guess, in turn reduces the carbon footprint.<achieve requirements with a minimal amount of servers>.But that's mostly from the hardware perspective, right? But not really from software perspective. I think, if that makes sense.

P8:

To be honest, I'm not so familiar with that area, but I just know gpu use the bunch of electricity, <gpu use bunch of electricity>so I can imagine that have like big impact on the environment.

P9:

Yeah, I think so. I think, yeah. Actually, in in my, actually, in my research field, ..If you want to train model, you some, some kind of model will be very energy consuming, so I think it would be better to get some more lighter algorithms. <training model consume energy>

P10:

Don’t know at all before this interview.<don’t know at all>

**RQ2**

**2.1.Do you think reducing energy consumption or carbon footprint is the responsibility of the developers of a piece of software?**

P1:

It's a tricky question. I was saying, um, I think when you have to develop a sitting and, I mean, implementing some kind of algorithm, whatever is there, is, it's hard to understand whether it will be high energy, will consume a lot of energy or not..<hard to identify energy consumption>I think that's more something that you discover on the way, meaning that you have high load on servers or whatever<high load on servers>. So I think it's hard in the process of develop the software to think too much about that.

P2:

Ah, yeah. Maybe Some people in the it industry do not pay much attention to this topic, but I think it's not just software and development development or companies. Everyone should need to be aware of the environment and then try to reduce energy consumption to protect our environment,<everyone’s responsibility> because this is our Earth, is our country. And we can do some actions, like turning off the lights or something you can do.

P3:

I think I agree with that..The software develop need to do some step to reduce energy consumption, our carbon footprint. It's kind of responsibility<developer’s responsibility>, and every one, or in or every individual, need to do some step to reduce the carbon footprint.

P4:

Oh, wow. Um, that's a very good question..It's not something that I ever thought about actually. Uh, so it's, I don't think I can give you yes or no answer right now, because I think I need to understand domain a little bit more in order to say if it's, it's the responsibility of the developer or some of the if it's more of like an organization responsibility<organization responsibility>.

P5:

however, of that, that's A tough question to answer. So, as developers, so there are multiple ways in which developers can contribute to reducing energy consumption. So in software, um, the number one is how efficient your code <efficient codes>is. Because if your code is very efficient, let's say, e.g. I'm building this Amazon website, right? If my code is very bad, the user, which is you, you have to spend a lot of time on on my website, like you click a button, you wait 10 s for something to happen, which means for those 10 s, there is some server somewhere working its size off to, you know, serve what you're requesting for. In other case, if my software is very efficient, if it returns the response in 1 s, instead of spending 10 s on one user, the server can actually spend one serve ten users in 10 s, which means we're reducing the servers, we are increasing the service usage,<increase the service usage> which means reducing the carbon footprint of that particular server.<reduce the carbon footprint of servers> So number one is the write efficient programs. So this is indirectly imposed on us, so we don't discuss when, wherever in the meeting. We don't discuss, like, okay, our server is, I mean, our code is bad, it's going to produce this much amount of carbon dioxide outside. No, we don't do that. But we are going to say, yes, our code is bad, the latency is bad, which means the moment when the user clicks on it, till the time here he sees anything meaningful, it's very long, which is bad for the business. Again, the focus is not on the carbon footprint. That focuses on the business, right? The focus is maximizing the revenue, which means lowering your cost. So efficient programs lower the cost of server deployment and increasing the written on investment. So speed website means good user experience, which means good for business. So it's indirectly. Everyone asks us to write efficient programs, asks us for better user experience, but they don't say we need to reduce the carbon footprint. Ah, maybe I deviated a bit um from the question, but do you think energy consumption are it is the responsibility of the developers? Um Yes, it is the responsibility of the developers.<reducing carbon footprint is the responsibility of developers>

P6:

Yes, maybe yes, the reason, it can be said in the department of the software, the company should take care of the product and all process of the product, the same thing as the developers.<company and developers take responsibility> It’s a part of the development of sustainability.

P7:

I think yes, in a way. So usually developers, um, it depends on the scale of the project, right? So if a developer, if their only task is just writing a code, then I think the most they can do is just try to write software and algorithms in a way that's efficient<write efficient code>. But if the developer also needs to think about the hardware, so in this case, um, do any estimations about how many servers once one application will need? <needed number of servers>So, e.g. if the developer or the softer architect um estimate that they will need 20 servers to run the application, but then in turn they figure out they only need ten, I would say it is their responsibility, in in a way, to try to reduce the amount of service if possible. But sometimes that can also be difficult, because, especially with services that are used by many users, or like are publicly accessible, um, we need more servers than necessary. Cases where we might expect that spike in requests, right? Like maybe the the service is trending on Twitter or something, and there would be like, sudden influx of users. So usually the service wants to survive that.<survive with more servers than necessary> But it also means the carbon footprint is higher, so I guess this can This has recently been solved by, um, something like Cuba Nattis, which does automatic scaling. So for most of the time, you have like, ten servers, and then if there is a spike in requests, we can dynamically increase that to 20, but that hardware still needs to be available, so it does not really reduce the carbon footprint that much in some ways.

P8:

Hmm, not so familiar, but, yeah, but I just understand we have some responsibility for that. <is developers’ responsibility>But I don't know the rule, and I don't know the like policy of that.

P9:

Maybe my 1st goal is actually to improve the accuracy<improve the accuracy> or the performance of the agreement..If maybe the performance or the increase is satisfied, maybe I will consider consider the energy consumption problem.

P10:

Yeah. I think it is everyone’s responsibility of reducing the energy consumption.<everyone’s responsibility to reduce energy consumption> So as a software engineer, I should also contribute to reduction of energy consumption.

**2.2 Do you personally have consider energy consumption or carbon footprint when developing software?**

P1:

I actually, if I look back, I mean, not the company work for now, but in the mid nineties, I used to work for the telecom company Ericsson, and there we had to write, actually write energy, um, we have to write software that didn't consume too much energy<design software that not consume too much energy previously>, because if we would have used too much energy, the processes would have melted because we didn't have, uh enough, uh, the circulation of airs took to cool them down. So we had to take that into consideration to not consume too many clock cycles. So that was the time when we had to do it, because otherwise the hardware would break. But today that's not the big issue in our type of software circle, so I think it's hard to put that responsibility director when you develop the software. <not consider today>The 2nd question I mean, when what I said, when I were curious and we had to do it, but it wasn't really based based on, I mean, it wasn't carbon in that case. It was just to to make sure that it was a sort of melt down the processes.

P2:

Ah, yeah, um, sure. E.G., when I used a sql to query some data or use some data house to get some information from the database, we should use some clearly and fast methods to get our information from the database. We have to clear and make our query methods clearly and faster to get this.<make codes clear and fast> Maybe. And it may be, uh, save our times, or save our energy or power to get what we want yet.

P3:

I think I did little, but it's not from my opinion. Is just like sometimes it's just a habit<habit>. Like, after finishing today s work, I would close some, close the television, especially the the code need to run for tonight, so I need to close my television or something.

P4:

no, I have not personally considered that at all.<Not personally considered> No, um, the only thing, yeah, when I have developed the consider sort of, the the response time<response time>, and make sure that you're not sending too much data, but not sort of from this more sustainability angle<not the sustainability angle>. No, never. So that, yeah.

P5:

I think no. Like I said, we do consider other aspects, like user experience, like the fastness, the speed of the website, the latency, how much store as it is, our our application is going to use, how much ram it is going to use. More usage means more number of servers, which is bad again, because the cost increases.<consider performance> So we think in those terms, instead of thinking as energy consumption.

P6:

I never thought about this. <never thought about it> For now, I’m starting thinking about this. I’m sorry.

P7:

um, I would say a little bit<a little bit>. So definitely, when writing code, or like software, I try to be as efficient as possible to make sure that I don't use any unnecessary resources<efficient codes don’t use unnecessary resources>. Um. But other than that, I would say I'm not that I'm not considering that much, but I know that that's something that I need to improve.

P8:

But maybe that is not for, like, another consumption. But I try, I every time try write a code, like, efficiently<write efficient code>, that I think that, like, in directory, right? Saved the energy consumption.

P9:

No, because actually,<not consider before> my algorithm is is not very energy consumption. And so, sorry, what do you mean by the automatic technologies?

P10:

Because I don't know how energy saving is reflected in the software development process before, I didn't consider it.<didn’t consider>

**2.3 At what development stages do you make this consideration?**

P1:

I said earlier, I will say that we don't make any considerations during uh development..It's more like when we actually run something in production and see that we for some reason, see that we are actually in overloading the systems, we need to do something about that. And I mean, overall, alone in the system, high means that it consumes a lot of the energy. But I would say it's more when we come to final testing and deployment<final testing and deployment>, and then it's normal, too late to do anything about it, unless it's I mean.

P2:

Yeah, maybe after code. Or, uh, some consider when, uh, we using some search why, or some a resource, or like something like that.

P3:

And also sometimes during, you know, submit the coding. And I need to test, test, but not so much testing. I need to, like, achieved a big function. And then I do some several tests, several steps, or every every tiny little change. I do the, I do the testing, it's my method, is my way to reduce the energy consumption.

P5:

And the next question, if I have to answer in terms of um, when do we consider this um? So we considered this um. It's not a one state some parts. So before we even start making an application, we design the application. So during the design phase itself, we're going to make some estimations. We're going to decide what technologies are we going to use, how many service are we going to have, what is the lord that we are expecting? All that. So that is the design phase.<design phase before development> We do that before we even start developing. So even there, we try to reduce. We try to maximize the resource usage, reduce the number of servers, reduce everything. So during the development, they write efficient programs. So 1st is the planning phase.<planning phase> We do that, we try to maximize the resources, which next is the development phase.<development phase> We again try to write optimal programs<optimal programs>, which is again, reducing carbon footprint. And next we come to a point which is called as load testing and scalability <load testing><scalability>and all that, which means we will pinpoint exactly how many service we need, how many redundant service for it. So wherever we develop an application for our company, if we think that we need five service, we don't deploy five service. We deploy ten service. Because the most important thing is, we don't want bad things to happen. We don't want it to affect business at the cost of more expense. In this case, even though we need five service, we deploy ten service, which will increase the carbon footprint. But that is the business, you know, losing a valuable customer is is more impactful than, you know, just spending some money for extra capacity. So yeah, we do it in all stages. We consider about optimizing everything in all stages.

P7:

Yeah, so in some ways, it's like during development, but in a lot of cases, I also consider that when planning a service, so e.g..if we have a specification of what the service needs to provide, and we have some estimates about the number of users that we might expect or something. <planning a service>It's like we try to, ahead of time, consider what will be the impact, and in this case, like the carbon like footprint, or the amount of servers and so on.

P8:

I see, like, the definition, the how to define the product and how to write a code. I think, then, uh, yeah, I make the conservation of that stage and implementing.

P10:

I don't know very well, but I feel that the recent rise of containerized deployment on the cloud will consume more energy?<deployment on the cloud>

**2.4 How did you assess the energy consumption or carbon footprint?**

P1:

So in that case, and I would say that again, it's more about, okay, how can we make sure that we are not using so much resources on the service, more than, say, talking about the energy consumption and assessing it, as I said, um, it's more that. It's more like, well, we discovered that we are loading the the service too much. It's not, uh, we not, we're not doing any, uh, a formal assessment of it. <have not done the formal assessment>Is more like, we discovered that that this is the case.

P2:

1. You know, maybe it's this may be difficult to calculate on it, or evaluate that this is really a problem.

P3:

Um, ah, how to say? I think for me, it's kind of hard..You know, during my working experience, it's kind of hard. I know all I need to do that. But I think maybe the team manager, or some management, need to consider this so much.<team manager> Yeah, yeah, yeah, oh. I think, I think it's a good way just to do something, to do, to reduce the energy consumption. Best. Sometimes we, we just think, or we just do some steps during our daily life. They closed the light or something. But during the working experience, especially when coding something, it's kind of hard, or we do not have this idea, like we need to do something to to reduce the energy consumption. But sometimes it's just like from your habit, I think it oh, how to say, I'm no, maybe I didn't do the access consumption before. Evaluated that one before.

P5:

Sorry, can you say that again?.That is correct. We don't evaluate energy consumption, but we do evaluate cost<evaluate cost>, which is directly related to energy consumption. The cost of service, the 1st and foremost design good systems. Design good software systems which are more efficient, consumes less cost and improves user experience<consume less cost><improve user experience>.

P8:

Uh, maybe. What I check is how memory I'm using now, and how wrong I'm using that memories question,<check memory usage> what action, maybe, what actions do you take to re receive the uh, gpu. conception also? So, so this is like, normally, I mean, normally I, or now in the future, normally, normally, yeah, I make my codes more efficient. I create more efficient code, e.g. E.G. like, uh, yeah, not using the right for loop. Now, I try to reuse for a code or more. Also, I think, like many right there. Yes, I just write a code, more agreeable code for other people, because then if I write a, like, light code, other people can easily, like, modify that code. I mean, other people also can try to make that code more efficient. So I think that's also right, read the reduce the energy consumption. So, but maybe we are, I think, how, what I'm thinking is how I can write the codes more efficient.

**2.5 What actions do you take to reduce energy consumption or carbon footprint?**

P1:

So, I wouldn't say that we are mature <not mature in company>in this area as a company.

P2:

1. when I made the Web pages, I thought about it, these problems. In order to make the web pages faster, or save up times or save resource, we we will take, took some methods to reduce our resource. Uh, e.g. we can use some on compressing images, or some more compressed music, or some easier way to kick click the bottom, or, uh, go to the next pages, the link to the next pages. <compress files><easier way to link to other pages>Maybe we use some faster methods or some compressed resource to do that?

P3:

I think it's kind of a similar, like before, I said, you may like, during the working working place, and A job, some unnecessary elevator, a some unnecessary, like coding or compelling. I need to reduce And also, I didn't, I need to close the television, A close television electricity or something. And also, um, you know, during the development of the television software, we need to think about software futures, like try to reduce the television electronic reading cost for a day. But for software developing during this stage, maybe are just a little action, maybe try to reduce some unnecessary test, or unnecessary, compelling, unnecessary coding review, like something.

P5:

So basically, you have to be a good software developer to do that, which everyone is trying to, you know, pick up. So I'm not saying I'm perfect, but I always try to improve myself. As a software engineer, if I'm a good software engineer, if I'm good at what I do, I indirectly reduce the cost. I indirectly improve the code, indirectly<improve codes to reduce the carbon footprint indirectly>, you know, reduce the carbon footprint. So there's not direct link, but indirectly, I'm all doing that. So what action do you need to take? I need to be a good software developer<be a good software developer>. That's my action. So improve your learning. Be a good developer. That's it.

**2.6 Do you write test cases to perform evaluation of energy consumption or carbon footprint?**

P1:

So we don't write test cases<don’t write test cases> either. Let's see that question too. Perform evaluational renging consumption, so we don't have anything like that.

P2:

Ah, not yet. Because it's a very creative topic. You know, we are not road such close to test.

P3:

I didn't create any test case about this one..Oh, I'm, I totally agree that if, if there is something, some tools like this one, I would use, definitely.

RQ3

**3.1 What are your opinions on the use of automated technologies to reduce the carbon footprint or energy consumption of software that you develop?**

P1:

1. I think it sounds like an interesting idea, to be honest..Uh um. And I think that if, if it turns out to be possible, I think it's a really great thing<great thing> to have. I'm not sure how well genetic program, for instance, could solve the problem. And sometimes it's hard. I mean, if you look at the as for instance, I might call the cold based I'm working with, it's about 5 million lines of code. So adding a few more lines of few, I mean, taking out a few lines, it's hard to say how much that would affect the total amount<hard to say the effect on the whole codes>, of course. So it's an interesting thought, uh, but if it works, it would be very interesting to use tools.

P2:

First. I think it should not affect the quality of the development for our UH software or web page, or something like that. <not affect the quality of development>This is should be go 1st and UH. and also, if we can keep our software, which have a great quality, I think it should be a very good way, and it should be promoted in the future. I think it. It's a very creative and very nice topic. And if it can make sense for our software developments to reduce the conceptions, or can protect our environment, which one of all the things is very good.

P3:

Yeah, I would like to use the tools that automatically reduce the carbon footprint. <would use>

P4:

yes. I don't know if there is any technology tools around, but I assume there is that job.

P5:

I'm on the job, I'm not sure how those work. But so right now, I'll tell you what's important for the business. You know what's important for the business is the company is they have a feature that they want to develop, and they have a criteria, and that's important for them no matter so and they want to do it in an effective way, which means they need to. If they are spending harder DN on developing this, they are expect hundred and one year at least as a return. It should be viable, financial, economically viable solutions<viable, financial, economically viable solutions>. That what's the business one. The developers, what they want is they want to write and they want to write a good code, secure code, and, you know, make the business requirements possible. Business team says that we need to do this, we need to do that in a cost effective way. And the developer, he does that, and, you know, deploys and everything. So when we develop the software and we deploy the applications, so the program that we write, it's not the same that is deployed to the service. So there is a compiler, right? Are you a computer science student? So there is a compiler which translates this, e.g., if I write it in Java, it translates Java according to bite code. And when it does start, it does a lot of optimizations already. So it does a lot of, you know, uh, e.g. it shortens the bite code. So even if you write a text file, which is, you know, ten and belong, the bite code is not ten and belong, it's just one and belong. So it does a lot of optimisations. It cuts down the code, and finally gives you a very compact, executeable that you deploy to the service. So there are already optimizations there. People may ask, what are you trying to optimize here, right? Are you trying to optimize the source code? If you're trying to optimize the source code? For me, I write the code, right? If someone is changing that code, if your code, if if the software is changing what I am writing, I should be able to comprehend it, but I should be confident that this is not doing something insecure. Security is an important factor. When the code is changed, I should be able to read the code, I should be able to work with the code, and it should be secure. <security of codes>That's what we need. What the company needs. If it does that, that's number one. So the code it generates, it should be secure, and the developers should be comfortable working with the new code.<be comfortable with the new code> That's one thing. The 2nd thing is it does not increase the load on the on the developer.<not increase load on developers> It does not increase the burden on the developer. So we, in the end, we get paid for the time we spend. Right? So, e.g., my company says, I have to spend 8 H in the company, which means I get paid for the amount of time that I dedicate to the company by adding this new functionality. If it increases my burden, if it increases my if it decreases my productivity, that's bad for business, and that's bad for, maybe, in some cases, developers. So if it doesn't decrease the security, if it doesn't, you know, decrease the productivity of the developer, if it is not bad for business. Yeah, it's all but I don't think there's any other reason why we shouldn't use it.

P6:

That’s great, because using this technology, I think I’m contributing to the global warming or reducing CO2, so it’s a very good option, <positive to use the tool>I think.

P7:

I think so. So I'm not really familiar with any tools like that..Uh, but if I try to think of, if I try to imagine that such tool would exist, or maybe it does exist, but I don't know about it, um, I think it would be useful to have, but I am curious like how that would be measured. Like what we could measure, like, a based on the algorithmic complexity, or maybe the speed at which the CPU is is running,<measure energy consumption methods> so let's say, like five gay hurts, or maybe like the energy, the energy consumption of the machine as a whole, that could be useful, but I'm, I'm not sure how to present that in a good way to the developer. So they could make, like, an educated guess, or maybe change something to improve um or reduce the energy consumption. So to summarize, I I'm not against it. I just can't really imagine how that would apply in in the real world. <not against>

P8:

Uh, yeah. I think that technology is really, like good, good technology. So, but maybe after I will ask you, but that that technology is normally the same of, like, writing, the code more efficiency. I mean, is there some difference of the, uh, writing code, of writing the same as the consumption? Or like, uh, yeah, when I think about, how can I save the how can I reduce it as a consumption? Like, what what I now, I think the right code efficiency.

P9:

Yeah, yeah, I think it would be very nice if we have some tool to automatically help us to reduce the carbon footprint, or energy to consumption, if it do not affect the performance<not impact the algorithm performance> of the algorithm.

P10:

If energy consumption can be reduced, I will happily use related tools<would be happily use> and technologies.

**3.2 If available, would you use tools that automatically reduce the carbon footprint or energy consumption?**

P1:

Of course.<will use the tool> I mean, the TIBCOS or other companies, uh, we want to have, I mean, to reduce the the amount of power our software requires. I mean, it's part of the whole green message we need to send to the world. To make sure that, as I said early, I don't really like bit coin mining and that kind of thing. So I like what the theory is doing, changing to a much more energy reduced algorithm for for the mining there.

P2:

If I can and got these tools or something like that, this will be very useful flower to, uh, make our software better. <sure to use the tool>

P3:

But I have a concern on whether these tools can totally reduced carbon footprint<concern on reduce the carbon footprint> and also didn't change the code structure and or the code logic<not change the code structure and logic>. I think it's kind of, you need to after you when you using this one, and you need to double check whether the function or whether the code is OK, just my opinion. So if all I didn't need to think, or as it's just kind of useful tool, I would definitely use that. <definitely use the tool>

P4:

So that.the idea sounds really good,<use such a tool> though, um that you can get help for doing that in a good way. So that's probably the answer to the 2nd question. Then, sort of, if there are tools available that works well in the environment that we operate, yeah, why? Why not?

P5:

Yeah. Does it make question? Would you use the tools?.Uh, yes. I, like I said, if if they, in a solve those problems that I mentioned, I would definitely use it here<definitely use the tool>.

P6:

Yes, I think it’s positive. But I don’t know the balance of the good factors of the CO2 and the better factors of the code. I don’t know the balance, at least, it has the good effect on the growing global issue. It would have a great positive impact on the worldwide, it’s okay.

P7:

Yes, See how, like, what what the result would be on some of our services, or some personal code, and then see if I can make some improvements to reduce the footprint..UM, I think I would definitely, if possible, I would try to use this tool locally, <would definitely try>

P8:

Yeah, yeah, I think yes. But, uh, I I'm interested in this area more mainly the Maybe that software help me to write the efficient code. Any faster running or, yeah, that kind of that help me, right? To write a faster code. I think I will use it.<faster running> Maybe, I just interested in that part.

P9:

Of course, I think, I think there's no, no harm harm to do to do this. Yes, this would be beneficial to the world.

**3.3 How do you foresee such a tool fitting into your development workflow?**

P1:

So if I had a tool, I see that, how did you see such a tool fitting in? In that case, I think that tool should be part of our normal CI/CD pipeline<part of CI/CD pipeline>. I mean, just a step in the pipeline. So on every commit, the developers get some feedback whether the the added code or change code is affecting the energy consumption<get feedback of reduction on energy consumption>. So that would be interesting.

P2:

Uh, because our development work flow, it's very flexible, and it's hard to protect, to foresee or evaluate how it will look like. So I think it may be a little difficult to, and it's difficult to for seeing such tours, because everything is exchanging. And, you know,Will develop it can be lost. Maybe, when I maybe I will use it for environment. And each new stages of software development, when I create a new part of um, go to the next stage for our coding.<after a new part code> I will maybe use these tools to check or to evaluate, to calculate on my consumption or something to Yeah.

P3:

I think maybe, uh, every morning after I come into the company, I would use that 1 H after work, before finish my whole day’s work, I would use that to to do that one?

P4:

I assume it would be, um, something that we would put into the CI/CD pipeline<CI/CD pipeline> somehow, um, in order to, you always want to get as fast feedback<get fast feedback>, uh, loop as possible, back to the developers..Uh, so I think that's why it would make most sense, sort of, um, similar to how we handle others, sort of security aspects, or others, sort of quality type of tools. Um. So yeah, I think that is probably the best way to put it. And then it would be used,

P5:

Right in the end, E.G. 1st business requirement comes in for the developers. And then we start developing the code, right? We write the code, we write the unit tests, we perform optimizations, all that and testing. The next step is testing. So so you are tool, whatever, whatever, this magic tool which optimizes the code, should come after this, after I develop, after I test it. So everything is done, it is ready to ship to the server during between these two phases.<between developing and testing phases> if your tool comes in, if it, you know, I send it, I send my code to your tool, it optimizes it. And then finally, we deployed to the server. That would be the ideal case. But again, the catch here is we trust the stool, right? So 1st we write it, whatever, in the current flow, we write the program. We tested using unit tests, or physical testing on data environment and all that. And then if you are confident, we deploy to the production environment. If your tool needs extra testing, right? So if it changes the code, so we need extra testing to make sure that what it does, it did not change anything bad. Oh, if that is the case, again, like I said, it adds more resources, human resources. We need to test again and again to make sure that it's not changing anything. Um, so, yeah, like I said, um, take job. E.G. We trust it, right?

P6:

If I have to introduce this system, I will fit this tool in the beginning stage. Because if I had decided to introduce the system, it’s easier than changing after the complementation. No, I think I would fit it into the end of the development, maybe. So introducing this tool, api, as developers, Firstly, I finish writing the all codes, and next step, I will call the api code, use it at the end of the development is better <end of the development>.

P7:

So during development. UM But also, I think it would be useful to have some integration with CI/CD,<integration with CI/CD pipeline> so maybe something like Jenkins that whenever any developer pushes some changes<push code changes>,

P8:

I don't, I normally don't like the, like, code assistance between I'm writing code, some some code systems change my code when I'm writing. I in my personally, I don't like it. So I, if I use this technology, I want to use the for testing. 1st, I write my code and and like the software, test my code, how that code, like, consumed energy after after writing code. <testing codes>

P9:

Okay, yeah, let me think about this, maybe. So if I have, uh, maybe, I will have 1st, have some algorithms, I will try to and the algorithms satisfy some criteria, e.g. some performance, some accuracy. And it can shave the accurate, but it would be very, how to say, energy consuming. And then I have such a tool, maybe I could use the tool to reduce the energy consumption. Since I think, actually, I'm not very sure, I think, let me think about this. Yeah, maybe maybe after I finish the develop <after finishing development>of the algorithm.

**3.4. When and how often would you use this tool?**

P1:

So it will be, I mean, it depends. I mean, if it takes very long time to run the tool, then we wouldn't do it for every commit, of course, because that would slow down our ability to have fast cycles. But I mean, if it's something that takes less than a minute or something, in that case, we will run it all the time.<run it all the time> If it would take hours, we would probably run it once per day or something. <run it once per day>I mean, during night time and when, but there's not not so much pressure on the the integration pipeline. <run time of the tool>

P2:

Maybe once a week, or once a month.

P3:

Yeah, yeah. After finishing a task, like when you developing codes a software, you need to divide the whole task into some some sub tasks<after finishing a sub-task>..So maybe after finishing a sub task, I need to use that. But so often, I think maybe once a day? Yeah, once a day<once a day>, or our, but all every two days. Use once.

P4:

I'm going into the next question there, then it would be used continuously<be used continuously>, sort of through the development workflow.

P5:

We write the code, we compile it, and then we test, we test our program, right? So if you trust your tool to be secure enough, it will come between these two phases development and deployment.<between development and deployment> Between these two, we will be using that.

P6:

f the system is not very completed and not cost too much time, then I will use it every time when I make changes the webpages. <every time code change> If there is no barrier to use it and not so costly, this is the important things for developers, I think.

P7:

Um, I think if it was well integrated with my development of our environment, I think, as much as possible<as much as possible>, and especially if it does not have a lot of impact on the actual development itself<not have a lot of impact on development itself>, like if I can write some changes and run that tool for, like, a short amount of time so it doesn't block my development, then I have no problem with running this, like very often.

P9:

I think it depends if, if the tool do not do not affect the performance, I think I will always use this to Yeah, but if, if, if the two are just, after using the tool, the performance of the cream just decreased so much. Yeah, maybe it would be better to Is it less? Actually, I think there's a trade off. <trade off between algorithm performance and reduction of energy consumption>

**3.5 Would you trust the results of tools that automatically reduce the carbon footprint or energy consumption?**

P1:

1. Okay, so we got and trust in the results, um, I think, to be able to trust the result of any tool, firstly, it needs to be a tool that is used by many<used by many> and a tool that has been proven to show correct results.<proven to show correct results> So, um, again, I mean, all results from any kind of measurement, you need to have confidence in it, and confidence you build by having others using the same tool, and, uh, speaking well about it and saying that it's actually doing good. So, I mean, I wouldn't trust the tool the 1st time I see it if no one else has used it, it needs to be proven that it actually does something.

P2:

Um 1st I think if the tools can, um provide me enough data and confident data to convince me to believe this without and it will not affect our process or some quality of our software, I will believe it.<provide confident data><not affect the quality>

P3:

Yeah. Um. I think before using that tool, I need to do some comparison or experiment about this one, whether this tool is truly can reduce <make sure truly can reduce>or couldn't. But if, after my own experiment, it truly can reduce, so I just, like the results, whether these two can truly reduce or not. And also, you know, when you implying that this one, it could not be interrupted your work, <not interrupt the workflow>your workflow are also the whole program in the workflow. So you need to adding that one in a suitable time our maybe this one would be managed, need be manager by a manager, like the project manager<be managed by a project manager>. All the software owner would maybe do that from from the whole perspective, not our own.

P4:

no, there there other I'm thinking of the similarity to security tools that sort of analyze your code base <security of analyzing code base>or something similar, that sometimes they give you a lot of false positives, and then you don't really like those kind of tools. And it might be similar with this kind of tool that in some cases it actually draws the wrong conclusion.<draw the wrong conclusion> But then there needs to be some way to sort of ignore those warnings, are sort of recommendations<need to ignore warnings or recommendations> or something, but otherwise, yeah, I wouldn't trust it<would not trust>.

P5:

Oh, this is actually a question Would you trust the results of that?.All, yes. I don't know. I don't trust it. I don't trust any software, really.<don’t trust> I don't trust it because because it is capable, of course, if it is capable of modifying the code into very bad for hacking purposes<hacking purpose>, of course you don't trust it unless it is its well out there, very tested, well approved.

P6:

I don’t know the genetic programming so well, if genetic programming can be explained for developers, if the process of reducing the carbon footprint can be performed, if the tool’s code will be open source, in this way, I can check the codes and the process and the reason to reduce the CO2.<open source> I will trust the tool for that reason. Understanding the codes and the process is important.

P7:

Um, maybe because definitely that tool would know more than I currently do..So I would think that tool can tell me the impact. But I would also be interested to see, like usually, if the tool gives me results about something, I expect to know how that was determined or how it was calculated,<how it is calculated> so I can verify that the tool is working correctly,<verify the correctness> or has like, actual, um, no false positives<no false positives> or something like that.

P9:

Yeah? Yes. What do you mean by trust? Yeah. I think it depends on how much I know about this too. If I know very well about how it works<know well about how the tool works>, maybe I will trust it. But if I do not know that, to have have little knowledge about it, maybe, yeah. It's hard to say. I think. I think, to me, I think the most important things it will not degenerate the performance <not degenerate algorithm performance>of the algorithm.

**3.6 What constraints would you require be met in order to use and trust the results of such a tool?**

P1:

I mean, to actually start using the tool, if I think I can trust it again. It depends on how well it will fit into our development processes <how well it fit into development workflow>and how easy it is to integrate it into a normal built pipeline,<easiness of integration> and, and so on. It's more like if it's priced. I mean, if you have to buy it, of course, the price has some implications as well. If it's very expensive, then you have to weigh that against how much are we willing to spend on detecting energy consumption erupt so that to more<finical consideration>, I mean, typical financial decision that needs to be taken as well. Okay, if it's free, um, I think that again, we are going, I think we come back to how easy it is to to set it up, an integrated thing to the normal daily workflows. And, I mean, I think it needs to, as I said earlier as well. I think, uh, needs to be, I mean, obvious that it actually is providing extra value for us. I mean, sometimes you can integrate tools that only shows that everything is okay, everything is okay, and you don't get any extra information. So if you would get some, I mean, extra information<extra information>, and again, if we already trust the tool to do the right thing, then I think it would be pretty easy to adopt the technology, the technique.

P2:

1. Uh, yeah, uh. The 1st one should be my money<cost price>. And how much? Where the tours it takes? Um, as you know, when we develop the new softwares, we have no money. We have living it resource and human resources such like that. So we have have to consider our resource and budget.<resource and budget> And we will also think about how long and these tools will Ah, well, you are well, you how long it will use for our software? Maybe it will um take one day or two day or more time. It's well make our process be more long, or it will delay our deadline, and we will maybe not use these tours. And also, um, it cannot. It do not affect the normal software develop development pro programs, and do not increase the invest of the human resource.<not delay the development progress> And it can provide our efficient data support<provide efficient data support>, uh, and maybe such like that. This three point Yes, yeah, I agree. Yeah. I think this too well relate the human results of the developer, because it can be achieved to change the source code automatically.

P3:

Yeah, did. This tool would not change the whole the software logic<not change the software logic> and the could you know, some sometimes when you are fixing the coding, you need to introduce another bug..So need to make sure that this kind of tools couldn't introduce any other bugs<not introduce new bugs>, or something in, I think, like what we talked before. You need to make sure that these two couldn't introduce another bug. And also, you need to make sure this true, can truly reduce the carbon footprint<can truly reduce carbon footprint>, or so I think these two.

P4:

Yeah. So I think what I just that sort of, if there are some kind of way to ignore, or, yeah, flag, uh, any warnings or such, uh, they usually needs to be some kind of mechanism for doing that..Um, when you have these these kind of tools that would analyze and diagnose your code, um, cause there, I think it's, it's usually very tricky to get a hundred percent correct<hard to get a hundred percent correct result>.

P5:

The wider community accepts it.<wider community accepts tool> It's not just companies don't start using the tools right away. You know, someone writes it doesn't do that. It must be accepted by the wider community before it is adopted into the into the company, or whatever. So yeah, I if it is, if it is up to me to select whether I trust the results or not, I will wait until the wider community accepts it. 1st, I will see this is doing good. I will try to, you know, understand as much as possible as to what it is doing, before I start posting this tool, you know, right? Security,<prove security> and I'm increase the productivity<not decrease productivity> of that does not decrease the productivity of the developers.

P7:

Um. So I think the main constraint or I require in this case would be that it does not use a lot of resources <not use a lot of resources>and development time<development time>..So the two should be, if possible, should be not interrupting any development work.<not interrupt development work> It's okay if it takes longer to end to analyze one that once the changes are pushed, because it can just run overnight. And I like, I don't need to worry about that. But if I use it during development, I would like it to not affect any of my development experience. And for trusting the tool, trusting the results, I think it would be enough to just see that it's accurate.<accurate> It it does not need, it does not need to be perfect. But as long as I can see that it actually helped me, like, reduce the carbon footprint, or, like the energy consumption, that would be good enough for me, I think. And um regarding trust, I also want this to be executed entirely locally<execute locally>, so not like as a remote service. I think, like, even if it, even if the company needs to pay for it, that's okay, as long as it runs locally. So maybe, like the company buys a license and then we execute it locally.

P9:

Yeah? And I think, maybe, maybe, is it something it would sound like, very restrict constraint things? Yeah, there's always the trade off, so maybe just do not be too harmful for the performance. I think it's acceptable. Yeah? When do you eat performance?

**3.7 What considerations do you think would encourage you or other developers to adopt such techniques voluntarily?**

P1:

I don't think I-I can't see that the developers, I mean, if it doesn't add any extra work to them, I mean extra work meaning that they need to spend lots and lots of time. I think most people would think that this is a good thing. <good thing>

P2:

1. Ah, on 1st on. Let me think we can answer these questions, not only but the development perspective. It's better for free to<tool is free>, um, yeah, it better to free for developments to use these tools. And maybe I got one count. I can share my account to my partner. Or are our team members to use these tools? Or, uh, we when we develop the softwares we develop, we take charge of different parts, but we can use the tool together At at the same time, we can use these tools and we can share the information. UH, at the same time, we can see what's the results of the and the other ones parts, UH, in these tools, and we can share the information<share information in tool>, and we can save our time, our resource to do that. Okay, great answers.

P3:

And also, maybe need to, like a teacher, to teach some something about this tool, like the whole flow. And what you should do, just to introduce this tool? , a guidance gets light.<need a tool guidance book> I think this idea is is super good. And you just consider them carbon footprint, and also is a related to our, not daily life, but related to the coder’s working, working environment.

P4:

Said. So, ah, yeah, um, it will probably be some kind of strategic initiative from the management team<strategy from management team>, I think. And also, good, yeah, it it, um, it needs to be talked a little bit more about, I would say, if it's sort of more generally known in the community, ah, that would also sort of help. And I'm thinking sort of in the future, sustainability is a big thing, sort of, so that would also sort of attract new talent to us. Uh, if we, if we worked really hard with that kind of think, um, but I do think that it needs to be a conscious management decision<conscious management decision>. And guess, introducing any kind of tool with cost you some time and money<investment of time and money>. So, um, it's not something you just do because you think it's fun or that you yeah, it. There needs to be some kind of return on investment thing for it.

P5:

Yes, honestly, um, if it is, if it comes from the company itself. So if my company says, hey, we have to do our part in, you know, global reducing the carbon footprint, so we have to do this, because it's our responsibility. And, um, we have to do it together. So whatever the developers can do, you should do it.<company’s requirement> If there is a such kind of, you know, encouragement from the business side, it's definitely useful, because anything that's not needed for successful business, it's not good thing to do. So if, e.g. me, I volunteerly take this up. E.g. I use this tool voluntarily to improve improve my code E.G. If anything happens, that's not me, that's not on the company. So I'm taking the responsibility for that, right? And I'm not willing to take that responsibility, because, of course, as much as you say that it's everyone's responsibility to reduce the carbon footprint, in the end, it is not needed for the business right now. right? I can. I can do my job without this. And if adding this is a risk to me, why would I do it? Right?<will not use it personally> Unless it comes from my company, right? You have to do it right. It encourages me to do it. Or if I tell them that I want to do it, and they are okay, and they are very supportive, then I will be willing to do it otherwise. Maybe not because it's not needed. It maybe for the projects I'm responsible, I would do it, but not for the company if it's not needed.

P6:

How much CO2 of the system reduced should be told to the users of the website. People want to themselves to contribute to the global issue by telling the reduction data. This will be beneficial for the webpages to be used by more people, I think. Showing the data to user will attract more users of the website. So the software developers will adopt this tool.<perform the reduction result>

P7:

I think for encouragement, the main thing would be to have visible results.<visible results>.So, e.g., if we, if the tool helps us discover some problems in our software, that which we can use to reduce the impact. And especially if it helps, this is useful, like for companies, especially if it helps reduce the electricity bill <help company reduce the electricity bill>or something like that, that's always helpful for, like, any managers or ceos, UH, to promote that stone.