Table S1. User requirements on design methods for resource-efficient offerings, supporting literature and their relative importance based on practitioner evaluation.

Category	Supporting literature	Requirements	Average	Standard deviation
Outcome	(Pigosso et al., 2010), (Alonso-Rasgado et al., 2004), (Shu and Wang, 2007), (Sandberg et al., 2005), (Ulrich and Eppinger, 2004), (Unger and Eppinger, 2011), (Dieter and Schmidt, 2013)	Useful in early design phase	3.8	1.01
		Provide quantified results	3.2	1.07
Process	(Ulrich and Eppinger, 2004), (Ullman, 2002), (Uflacker and Zeier, 2011), (Shimomura et al., 2013), (Van der Merwe, 2015), (Ming et al., 2008), (Sampson and Spring, 2012), (Yin and Ma, 2012), (Bouchlaghem et al., 2005), (Marras and Hancock, 2014), (Zuehlke and Thiels, 2008)	Support prioritization of improvement areas in design	3.7	0.86
		Support communication across relevant actors	3.9	0.96
		Support collaboration across relevant actors	3.6	1.16
Content	(Chen et al., 2011), (Cocca and Ganz, 2015), (Gu and Sosale, 1999), (Ghahramani and Houshyar, 1996), (Maussang et al., 2009), (Ashworth et al., 1996), (Crowder et al., 2012), (Durugbo, 2013), , (Goh et al., 2009), (Heisig et al., 2014), (Isaksson et al., 2009), (Jagtap and Johnson, 2011), (Shu and Wang, 2007), (Vianello and Ahmed-Kristensen, 2012), (Wong et al., 2008)	Support lifecycle thinking	4.1	0.79
Time and cost	(Sakao and Lindahl, 2015), (De Benedetti et al., 2010), (Chou, 2014), (Chou et al., 2015), (Lindahl, 2006, 2005; Lindahl et al., 2014), (Cheaitou and Khan, 2015)	Low cost of usage	3.8	1.14
Users	(Lindahl, 2006, 2005, 2004), (Sakao and Shimomura, 2007), (Unger and Eppinger, 2011), (Heisig et al., 2014), (Reich, 2010), (Vasantha et al., 2012), (Ming et al., 2008), (Zarpelon Neto et al., 2015), (Courage and Baxter, 2005), (Chakrabarti and Lindemann, 2016)	Easy to use	4.4	0.82
		Easy to learn	4.2	0.96
		Support designers' creativity	4.2	0.87
		Provide learning opportunity	3.2	1.02
		Support management of multiple projects	3.4	1.21

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Table S2. Characteristics and qualifiers for the development and selection of design methods for resource-efficient offerings before the workshops.

Supporting literature	Characteristic	Qualifier	Brief description[1]
(Aurich et al., 2006; Geis et al., 2008; Le Pochat et al., 2007; Lindahl, 2005; López-Mesa, 2006; Müller et al., 2009)	**Customizability**	Modularization	Parts of the support can be used separately by individuals or omitted entirely
		Adjustability to existing company process	Parts of the support can be used separately by individuals or omitted entirely
(Jänsch and Birkhofer, 2007; Tukker, 2015; Vasantha et al., 2012)	**Simplicity**	Simplicity of data addressed	Dimensions and uncertainty of data addressed by the design support.
		Simplicity of entailed process	Number of steps, iterations and conditions evaluated in the processes.
(Ball and Christensen, 2009; Lindahl, 2006, 2005; Lofthouse, 2006; López-Mesa and Thompson, 2006)	**Flexibility**	Input flexibility	Support is capable of accepting different types and qualities of data.
		User flexibility	Support can be used by individuals or requires a workshop-style environment.
(Birch et al., 2012; Birkhofer et al., 2002; Knight and Jenkins, 2009; Wallace, 2011)	**Scalability**	System scale	Support focused on the solution in its entirety or parts of it.
		Time scale	Support focused on certain aspects or the entirety of the lifecycle.
(Arai and Shimomura, 2004; Geis et al., 2008; Lindahl, 2005; López-Mesa and Bylund, 2011; O'Hare, 2010; Sakao and Shimomura, 2007)	**Transparency**	Tool/Software	Support is aided or not aided by a digital or analog tool for execution.
		Handbook/Screencast	Support is aided by a digital or analog material for understanding.

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[1] At this stage of the support method's application, the term *support* was used instead of *method*. This was later adjusted for clarity.

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Document S.3 – Supplementary material
This supplementary material details quotes from different stakeholders involved in the study.

The voices of the method developers

Who is the recipient?

The academic panel strongly agreed on the importance of the characteristics identified and mainly insisted on the clarification of ambiguous aspects. The panel required only one new characteristic to be added, focusing on the recipient of the outcome of the method's use:

> I am looking at the characteristics, and maybe it's in there [the previously identified characteristics] for you, but then it needs clarification. The purpose of a [method] in the sense of whether it is for me as a designer to take a decision, and I am the only audience of the output of the tool is very different, than if I have to convince my boss or my client that it's the right decision. […] Take LCA as the best-known tool. As a designer, I want something I can do in an hour and continue. I could never go with the result of an LCA after an hour […] to my business manager. He will say: "What is this, I can't take a decision on this." *(Expert B)*

In agreement with this notion, the panel saw it as very important for the characteristic "recipient" to be added as a sixth item.

> If I were to select a [method] that would be one of the characteristics that is most relevant in selecting whether it is fit for purpose. That's why designers always fight with sustainability people about what an LCA is. *(Expert B)*

Clarifying the importance of prior knowledge of method users

A key aspect raised was on the topic of the knowledge and capabilities of the method users. Although this was remarked in the characteristic "flexibility" and the description given to the workshop participants, the panel was clear that this aspect must be stressed further.

> The level of knowledge that the user needs to have to apply the [method] for a specific purpose is also important. It is essential that the intended user has the required knowledge and skills for the application of the tools/methods. For example, ecodesign tools that require a high knowledge level on environmental issues might be less applicable for designers than for sustainable design experts. *(Expert C)*

Expert B pointed out that the knowledge requirements imposed by a method *both* on the user (person or group using the method) *and* the decision maker (receiver of results) are key method characteristics and are critical for method design and selection.

As a result, the qualifier "user flexibility" under the characteristic "flexibility" was reformulated and sharpened, and the aspect of knowledge required to understand and act upon the results of using the method was included in the description of both.

Interdependency of characteristics

An observation made was, that concerning some of the identified method requirements, the characteristics found are not entirely independent:

> The characteristics sometimes seem to be interdependent. For example, sometimes customizability and scalability [are] a way to realize flexibility. *(Expert A)*

Based on the discussion, this aspect had to be clarified, both with respect to the characteristics found as a result of this research and with a focus on other characteristics users of the general procedure for structured development of design methods may identify.

Ambiguity of the "time scale" qualifier under the "scalability" characteristic

During the discussions, it became obvious that the aspect of time scale can be ambiguous, depending on whether the question of the lifecycle phase(s) in focus of the method's execution or the time it takes to execute the method as such is in focus:

> When I first read "time scale" in the title, I was thinking about the time it would take to apply the tool during the design process, but it could also be related to which phase of the lifecycle the [method] is contributing. I think [both] of them are important, so maybe also adding this timescale [would be worthwhile]. *(Expert C)*

As a result, both "time scale" and "simplicity of entailed process" were clarified.

Target audience of the proposed procedure and the identified characteristics

A further key aspect was raised concerning the circumstances both the proposed procedure and the identified characteristics would be applied in:

> I think this […] is entirely aimed at happening inside reasonably sized industrial companies. In-house design. Because the situation if you are a designer at a design agency, working for industrial clients, is completely different. If I am in one company that does one type of product, I want to be able to be specific for that case. If I am in a design agency, I can be doing packaging today and an automotive chair tomorrow, and that needs far more flexibility. […] This is something that needs to be made explicit. *(Expert B)*

The voices of the method users – Adjusting method characteristics with practitioners

This material provides insight into the discussions on the identified characteristics and requirements. To facilitate the discussion and to make it more tangible, *Practitioner A* proposed a design challenge he is currently facing in practice. To ensure the anonymity of *Practitioner A's* employer only a rough description of the design challenge can be provided:

> The current [devices] are predominantly made of steel, with largely lead-based batteries. Now, the goal is to move towards a carbon-fiber construction, with lithium-ion batteries. The current procedures do not allow for such radical change; rather, what is provided as an outcome of applying current techniques is a roughly identical device, with the smaller, lighter lithium batteries and additional lead weights to make up for the loss in mass to ensure stability.

After that, the discussion centered around the expected impact of focusing on the design method characteristics in developing methods for design tasks towards resource-efficient offerings. The relevance and importance of the presented characteristics were confirmed:

> The system scale is really important. It's hardly anyone that has the knowledge of the whole scale. So, a design [method] should help with that. *(Practitioner B)*

Further, the proposed challenge directly related to the qualifier "adjustability to existing processes" under the "customizability" characteristic and was seen as very important to take account of in the development of design methods. With regards to the qualifier

"modularization" under the same characteristic, there was a broad agreement of its high relevance to support meeting the challenge detailed above. Also, the question of simplicity and data was agreed upon:

> Well, we are moving from generalization to specialization, so we don't do average anymore. We do exact. So that drives a lot of indisputable facts, actually. […] We can actually have numbers for everything. Every checklist item that we used to say yes or no for, we could sort of sum up to. […] And then it would be interesting to understand: What are the uncertainties in these numbers? Because we get 3, 4, 5, 7 digits after the comma and then we think this is the truth. And then we act on that one. But there could be estimates and a lot of uncertainties that we really don't have a good way of managing. *(Practitioner A)*

With respect to the qualifier "user flexibility" under the characteristic "flexibility", Practitioner B gave an example underlining its importance:

> [In a project,] we were just discussing a checklist, and I was the leader of that meeting. I tried to ask questions in a good way, but I didn't have the experience for example in the workshop. And then another person came into the room and helped me, and she has got a lot of experience and she could see in the designs […], will it leak here. And they said yeah, it leaks, because they took away the plumbing and put it away. Well, I don't have the experience to see that, but she asked the specific question. […] So you cannot just ask: Is it better or worse than another design? *(Practitioner B)*

In addition, the relevance of the characteristic "recipient" became clear in this circumstance, as clearly Practitioner B was not the correct individual to assess the method result. On the same note, the issue of the qualifier "input flexibility" under the characteristic "flexibility" was discussed as an aspect to be considered when implementing a design method:

> We did this checklist because first we had a type of FMEA [Failure Modes and Effects Analysis], which was very general. […] And now, we are very distinct [precise], but there is still room for uncertainty. So it's a very important aspect. *(Practitioner B)*

After an in-depth discussion, the participating practitioners made clear that they see the relevance and importance of all characteristics proposed. A key aspect that was critical for the practitioners and not represented among the eleven characteristics identified prior to this workshop was the issue of "traceability and accountability", explained by Practitioner A using the example of a checklist as a very simple design method:

> In my opinion, you should look into the process of checking that checklist. How did you come to the value that is put there? Is there an automated solution? […] Because I see that could be most of the reviews on a project: The first time, there could just be one setting crosses saying "That's fine." And moving on to the next one. […] So we have the checklists, but we don't have good processes to actually check the checkbox. […] There could be different responsible people for each of those boxes. […] So it's about accountability for the process of who is checking the checkbox. Because there is no owner of the process for this. So do you have a good process for checking the checkbox? *(Practitioner A)*

Later in the discussion, the following remarks were given, providing further insight into the intention and direction of the new design method characteristic "traceability and accountability":

> From my perspective, I would like to have some kind of, let's call it, domain approver, who is responsible for the outside view of the project into this checkbox. So he or she will look into

> the checkbox every time [inaudible], so that you understand that well, doing this thing, it's working out fine. […] So this domain approver will be responsible for the process [effective execution of design methods], where you actually know what is the worth [of the method result]. *(Practitioner A)*

The practitioners further made clear the critical importance of enabling interaction between staff with different skill sets in order to ensure shortening development times and meeting current market demands:

> When the [development] process is too long, the market has changed so much that there is no market. So it needs to be quick and has to be really, really focused on the market. Then you need to understand that the user really wants this, and that could be from an environmental perspective [or another]. So the connection [between different internal actors] is so interesting.

At the conclusion of the workshop, one of the participants made the following statement:

> It's interesting you don't only develop new methods, [enable putting them] in a matrix where the recommended use, different aspects and characteristics [become clear]. I think that's very interesting! […] I think it's very good that you do that. There are so many tools that are made, so I'm happy that you do that. *(Practitioner B)*