Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
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Swiss Confederation

Federal Department of Economic Affairs,
Education and Research EAER

Commission for Technology and Innovation CTI
Innovation Promotion Agency

MicroPBR 4D: Développement d`une nouvelle génération de ferme à algue à haute productivité et à énergie positive.

Management Summary
The R&D project involves the development of a proof of concept of a microPBR that performs solar digital photosynthesis.

The goals of the technological innovations of the microPBR are to improve limiting factors of current photosynthesis by addressing the sun light to biomass conversion bottle neck and the density limit of liquid algae culture.

MicroPBR combines a closed algae culture, a solar energy production and a liquid treatment facility into one.

Type of Project
R&D project (Default)

R&D Sector/Discipline
Life Sciences / Other Life Science technologies

Project Partner Overview

Project start
23.09.2013

Project duration (in months)
19

Financial Overview

Financial Overview	Total [CHF]	Business [CHF]	Research [CHF]	Cash Contribution to RP by IP [CHF]/[%]		Total Business Contribution [CHF]	Funding Request [CHF]/[%]	
Project Labor Cost	0	0	0	0		0	0	
Additional Expenses	0	0	0	0		0	0	
Total Project Cost	**0**	**0**	**0**	**0**	**0%**	**0**	**0**	**0%**

Project Overview

Work Package	W4	W8	W12	W16	W20	W24	W28	W32	W36	W40	W44	W48	W52	W56	W60
Project Management (DEFAULT)	1														
Virtual LPU unit			2												
LPU parts construction and assembly					3										
LPU testing						4									
Milestones						♦ 1 ♦ 2				♦ 3					
Labor cost [CHF]						0 0				0					
% of Total project cost						**0% 0%**				**0%**					

Work Package	W64	W68	W72	W76	Project Contribution Labor Time	RP/IP
Project Management (DEFAULT)					0%	0%
Virtual LPU unit					0%	0%
LPU parts construction and assembly					0%	0%
LPU testing					100%	0%
Milestones					100%	0%
Labor cost [CHF]						0
% of Total project cost						**100%**

1. General Information

1.1 Project Title
MicroPBR 4D: Développement d`une nouvelle génération de ferme à algue à haute productivité et à énergie positive.

1.2 Project Title in English
MicroPBR 4D: Development of a new generation of high productivity and energy positive algae farm.

1.3 Management Summary
The R&D project involves the development of a proof of concept of a microPBR that performs solar digital photosynthesis.

The goals of the technological innovations of the microPBR are to improve limiting factors of current photosynthesis by addressing the sun light to biomass conversion bottle neck and the density limit of liquid algae culture.

MicroPBR combines a closed algae culture, a solar energy production and a liquid treatment facility into one.

1.4 Type of Project
R&D project (Default)

1.5 R&D Sector/Discipline
Life Sciences / Other Life Science technologies

1.8 International Project
none

1.6 National Thematic Network (NTN)
none

1.7 Swiss Competence Center for Energy Research (SCCER)
none

1.8 CTI Innovation Mentor

Have you received any support from a CTI Innovation Mentor?
Yes

Name
Torres, Pedro

1.9 Continuation of CTI Project
none

1.10 Continuation of SNSF Project
none

1.11 Language

English

2. Partners

2.1 Partner Users (Research and Implementation Partners)

2.2 Partner Companies (Implementation Partners)

2.3 Partner Institutions (Research Partners)

3. Project Context

3.1 Which funded projects does this project rely on?
None

3.2 What other funding agencies and programmes are intended to support this project?
OFEN, MyCimate, private sponsors

3.3 Do you receive further financial support for this research area?
None

4. Innovation

4.1 What are the key elements of the innovation created by this project?

MicroPBR 4D can be defined as a photo-bio-reactor for micro-algae culture that can be a thousand time more productive compared to a basic micro-algae pound photobioreactor, on a square meter of land used for culture basis.
MicroPBR 4D allows for beyond liquid cell density threshold culture in the three dimensions of space and with digital lighting at different time scale dimension, bringing a fourth dimension.
The goals of the technological innovations of the microPBR are to significantly improve limiting factors of current photosynthesis by addressing the sun light to biomass conversion bottle neck and the density limit of liquid micro-algae culture.

MicroPBR also address the energetic balance issue of current micro-algae culture system by reducing thermal and mechanical energy spending.
It also integrate solar thermal technology in order to make full use of remain solar energy.
Reduce energy spending and energy production should make microPBR a net energy producing facility.

LPU unit of microPBR4 D thus allows for parametric digital photosynthesis but also full use of solar energy and bring a positive energy balance.

4.2 What is the strategic relevance of this innovation to the implementation partners?

Competitive edge:
This new type of biomass production facility is very complementary to conventional biomass production in field. It can bring value to their CO2 emissions, resolve digestat storage and treat nitrate excess thus reducing overall manure treatment cost. It produces massive yield which are mostly insensitive to climate variations which can smooth overall production.
For the farmer who has a biogas plant, a microPBR could become a perfect complementing facility.

New product line:
For the farmer it greatly enlarge the diversity of raw material and rare compounds that a farmer can produce in mass. Some of which could be directly used in the farm for animal feeding or soils complement for example. The bulk of this high quality high value biomass could be send to oil or sugar refinery.

For the microPBR technology developper the use of optic technology, solar thermal existing technology in a new generation of photosynthetic biomass system is opening a all new market for the development of new line or product.

4.3 What is the strategic relevance of this innovation to the research partners?

The current state of their own research might be improved in several field of applied science.
There might be a knowledge increase in the use of light capture and reflection technologies coupled with infrared energy transfer.
In the field of automation, modern optical devices should be synchronized with measurement apparatus for the developpment of advanced biotechnology application.

4.4 How do you assess the impact of the project in terms of ecological sustainability?

4.5 What is the overall potential of this innovation?

Micro-algae culture has become an important research subject for government and private industry on the international level for its implication in several strategic sectors.
For instance a lot of attention has been focused on using micro-algae as an energy source for sun to hydrogen, sun to biodiesel or biological waste to biodiesel production.
Unfortunately all of these projects where expecting a large increase in the price of fossil fuel to become profitable. With the evolution of the energy market environment, dominated by relatively low cost fossil fuel from shall gas, this type of energy applications fade away.

However micro-algae culture is still a profitable sector and scientific research topic when it comes to cleantech, for instance in waste water treatment especially for the nitrate treatment.
Microalgae culture also has profitable applications in the production of health food complements and production of specialized molecules for pharmaceutical industry.
Research is also going on the use of micro-algae culture as model for GMO technology in enclosed culture, using the advantage of high productivity and a wide cell type available for genetic constructions.

The new scientific finding expected is to bring a new world class technology for growing micro-algae that allow to combine all of the profitable sector.
In deed a microPBR 4D will offer the same cleantech qualities but also guarantee high quality organic biomass production with for health food or pharmaceutical production standard.
The microPBR 4D is also a unique tool for biotechnology by offering a high control production device with light control gene regulation.

Not been able to execute this project would lead to a lost of opportunity to take a leading role in research and industrial technology not only in cleantech but also in advance biotechnology.

5. Business Case

5.1 What are the business objectives of the project?

Long term business objectives initiated by the proof of concept of the LPU :

Key figure :
Six years of research and development of the technical solutions for the carbon negative industrial ecosystems, for in land and sea shores.

Know-how :
Master's degree in functional biology with specialization in microbiology and chloroplast molecular research.
Business development skills based on cleantech and biotechnology industry knowledge.

Markets : The carbon negative industry has ramifications in several markets that can be classified as such :

1. CleanTech :
    1. Quantitative carbon compensation
    2. Nitrate absorption for treatment of excess in animal raising farm
    3. Heavy metal recycling

2. Carbon neutral raw material :
    1. Complex and high quality lipids
    2. Complex and high quality sugars
    3. Protein rich cake for animal feeding : Fish and other
    4. Oxygen production
    5. Micro structured carbonate particles of different size and shapes
    6. Other valuable compound : Antioxidants, active enzyme for instance

3. Carbon neutral energy generation :
    1. Thermal solar / Biogas carbon neutral electricity generation
    2. Thermal solar / Biogas carbon neutral heat generation

4. Customers :

The customers of microPBR are expected to be farmers of all type but preferably with emissions from a biogas plant. Due to the fact that microPBR 4D are compact, high density and modular facilities, they can fit existing installation in the country side, in urban farming or industrial context.

5. Business idea :

The business idea is to develop an entire industrial ecosystem with products like :

1. microPBR 4D
2. zero carbon micro algae nutriment complement capsules
3. selected micro-algae strains
4. green chemistry process for micro algae biorefinery

These products will be designed for optimized compatibility. The product integrated in this industrial ecosystem will gain competitive edges.
For these products, the commercial advantages will come by profiting from the development of such ecosystem in a first phase and by profiting from the stability, sustainability and predictability of such industrial ecosystem in a second phase.

6. Motivation :

The environmental challenges our generation and future generations are facing, including climate change, non polluted water supply shortage, land fertility reduction, biodiversity drastic reduction and air pollution are a source of serious concerns. These crisis are also a source of possible opportunities as they will force mutation in the actual industrial complex way of production.
The transposition of a carbon pumping ecosystem into an industrial context is an attempt to bring more harmony between economical and ecological constrain. The development of solar digital photosynthesis with the proof of concept of the LPU is an attempt to to bring more harmony between technological and natural process.

7. Market innovation :

They are several market innovations.

<u>Creation of new market value chain:</u>
One of the idea behind it is to bring value at both end of the value chain. The microPBR is in the middle that value chain. It create the demand for nutriments complement supply from industrial waste currently use as low value application for road filling. The use of industrial waste as a source fertilizer is not new. However the development of micro-algae intensive culture that allow microPBR can generate enough demand and volume to create a new specific market of carbon neutral fertilizer for micro-algae from industrial waste.

<u>Market hybridization:</u>
Another market innovation is to hybridized two different markets solar energy generation and intensive micro algae culture into the same device market to farmer.
The development of the proof of concept of the LPU will show that it possible to use the same facility for both solar energy generation and digital photosynthesis. The idea is that two current facilities with long pay back time can be combined for the price of one and reduce the pay back time.

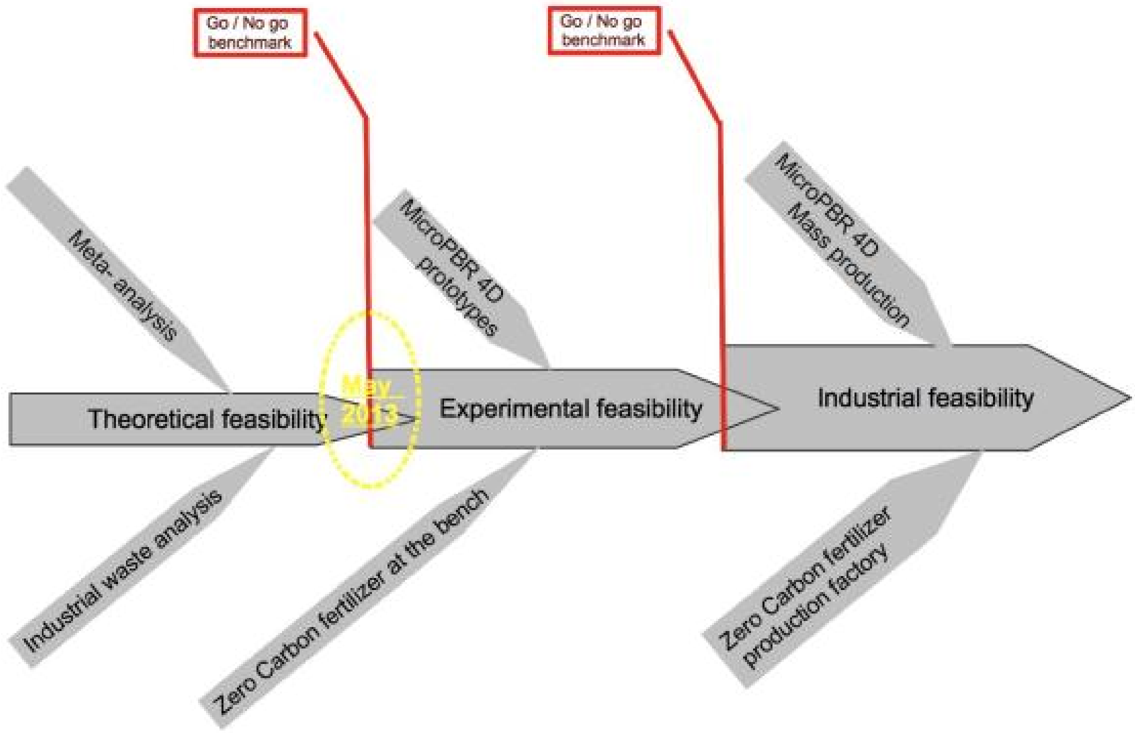
5.2 What are the project outcomes?

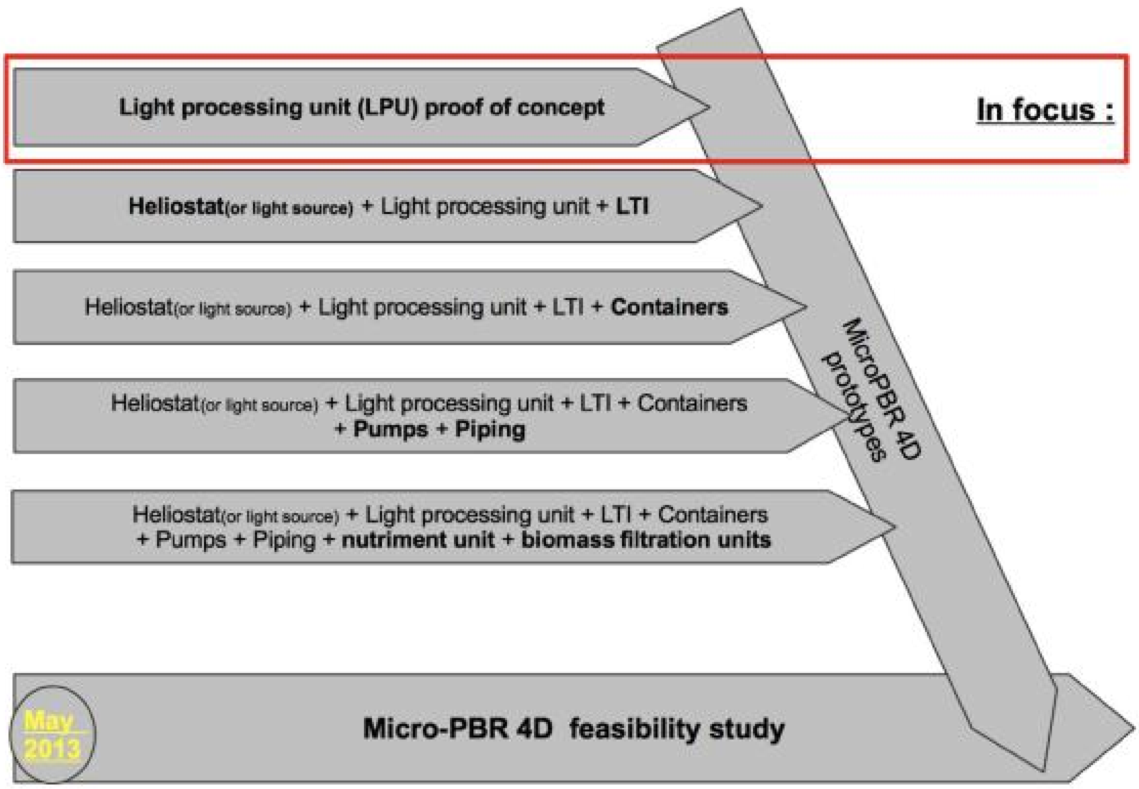
The planned results is as followed (annexe planned results diagram):

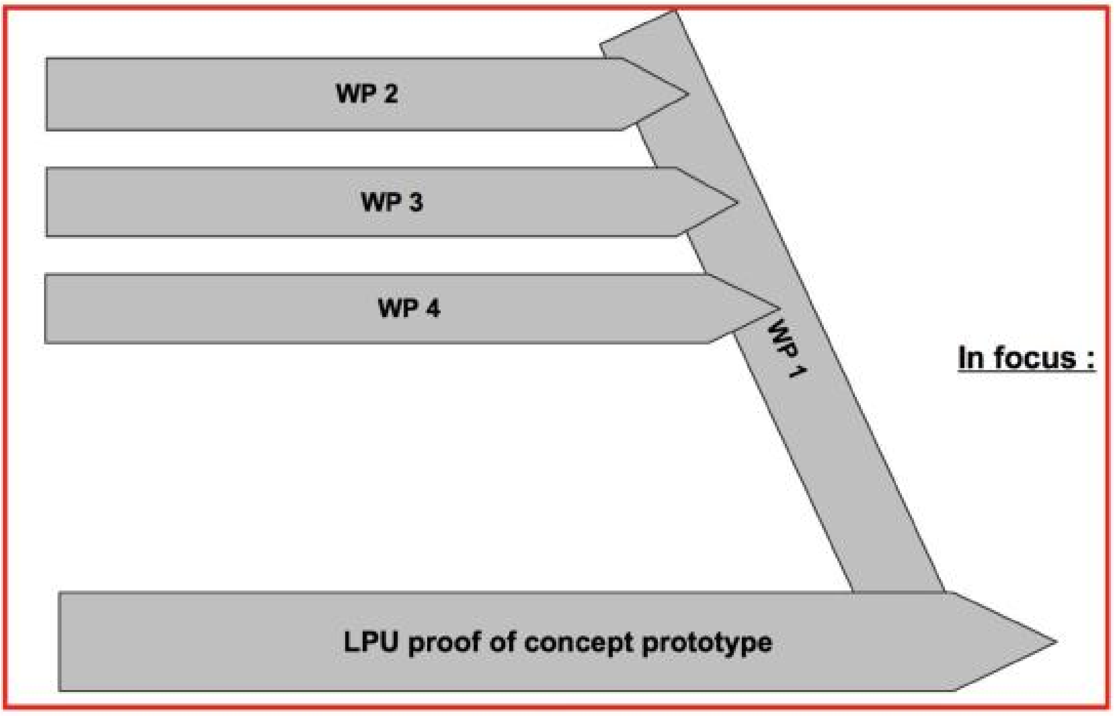
Prototype of the LPU for a proof of concept of the use of sun for digital photosynthesis.
This LPU prototype should demonstrate light channeling, energy positivity with infrared energy transfert, PAR increase with UV conversion, light wave length improvements and milisecond light focusing at different locations.

A LPU prototype proven to be functional could be directly use for a service of on site measurements of potential production of microalgae culture using digital photosynthesis.

The LPU prototype should integrate a following microPBR 4D feasability study. At the end of the following experimental study, a microPBR 4D prototype could be used for microalgae biological study.


Go / No go benchmark
Go / No go benchmark
Meta- analysis
MicroPBR 4D prototypes
MicroPBR 4D Mass production
Theoretical feasibility
May 2013
Experimental feasibility
Industrial feasibility
Industrial waste analysis
Zero Carbon fertilizer at the bench
Zero Carbon fertilizer production factory


Light processing unit (LPU) proof of concept
In focus :
Heliostat(or light source) + Light processing unit + LTI
Heliostat(or light source) + Light processing unit + LTI + Containers
Heliostat(or light source) + Light processing unit + LTI + Containers + Pumps + Piping
Heliostat(or light source) + Light processing unit + LTI + Containers + Pumps + Piping + nutriment unit + biomass filtration units
MicroPBR 4D prototypes
May 2013
Micro-PBR 4D feasibility study



5.3 What are the measurable commercial benefits of the project?

This particular CTI project is focusing on a proof of concept of an light processing unit (**LPU**) for digital photosynthesis with sun light.
It is mainly a prototype to prove the scientific idea behind the concept in order to justify further investments in patent research/filling and further feasibility studies.

However the LPU produced by the end of this project will be functional object that can serve several purposes.
They will primarily serve as a research tool in following feasibility study concerning the development of the microPBR technology. They will also be used as in field measurement platform necessary for the quantitative modeling of carbon negative industrial ecosystems in Switzerland or else where. They could also be used for other studies to experiment digital photosynthesis with the LPU.

It is not expected to bring significant and immediate financial revenues as it is a step toward the development of an innovative product line of microPBR 4D.
However it is expected to bring several commercial benefit to have a LPU unit ready in formof patents and a leading position in the market of advance photobioreactor.

5.4 What is the added value for the Swiss economy?

Jobs for different sectors of the Swiss economy :

This project can create job for highly skilled worker involved in the development of the microPBR technologies at the interface of biological science, chemical and physical science.
It also can create job for the development of applications of the different products derived from refinery of the biomass.

The massive production capacity combined with the diversity of biomass type available can make microPBR an interesting source of endogenous raw material for the Swiss pharmaceutical, chemical, agriculture, food and beverage industry.

This new source raw material coming on the market with a big difference on the risk of future production compared to climate sensitive biomass production can create an opportunity for the development of structured product specialized for this new type of production of raw material.

Finally it can create jobs at the local level for the microPBR installer, the farmers exploiting the device and at the recycling facility of our endogenous waste, all of those jobs cannot be delocalized.

The IP right strategy:

The microPBR IP strategy can be based on microPBR outside design, patents for optimized technical solutions for the elements (LPU; LTI, others...) of the microPBR and for the technical solutions for an optimized combination of the elements.
The model where the microPBR parametric environmental factors program is associated to selected strains and specific nutriment complement capsule,s can be use to make a combination of industrial secrets, individual patents and combination of patents.

CarboRock startup project:

A Swiss startup project , CarboRock, is foreseen to be created and to commercialized the IP portfolio under a single brand name. A commercial and brand development will be also specially constructed to market the microPBR 4D technologies.

Sustainable products:

By the nature of the business model, there are several products and services that could be delivered in a sustainable manner. For products there are the supply of certified compatible starter culture, nutriment complement capsules, microPBR technical upgrades and replacement parts. As for services, there can be a biological technical support and control certification services.

Strengthening of regional job attraction:

It can strengthen the attraction of regional job in the agricultural and waste management sector by bringing a new diversification potential by improving overall productivity of existing facility by adding value to farm and industrial waste treatment. It also strengthen the regional job attraction in the life science sector by bringing a new tools for research in photobiology, micro-algae and a future industrial platform for biotechnological applications.

5.5 What is the underlying business model?

MicroPBR 4D have a direct use on the farm by treating nitrate emission and improving CO2 balance of a farm. However it should not be only considered as a cleaning device. It brings a whole new wide range of biomass types that can be produced depending on market demand.
The underlying business model can be understood with an analogy to capsule coffee machine.
The coffee machine being the algae farm and the nutriment the capsule.
Farmer could choose among a catalog of strains type, use the nutriment flavor capsule that goes with it and just choose the corresponding parametric program to start a strain specific digital photosynthesis.

The nutriments capsule will be made from recycled raw material coming out of actual waste management facility. Making the overall value chain a cleaning up process tight to an industry growth.

5.6 What are the key figures of the business plan?

The joint business plan (BP) with projections concerning the business of industrial microPBR 4D sales in Switzerland, gives only early estimations (Agriculture data from OFS).

Facts and numbers about the sales volume potential in Switzerland:

A microPBR could be implemented nearly anywhere but best integrate a site with existing emissions that need to be treated as it is the case with a biogas plant.
The price estimations in the joint BP were made for a microPBR unit with an hectare of sun capture area in Switzerland, which should be sufficient to treat CO2 emissions of a biogas plant of 50kWh.

The number of potential sites in Switzerland for microPBR implementations is relative to the number of industrial and farms with biogas plants. The Ökostrom association, one of the biggest association of farmers producing green energy, mainly from biogas plants, regroup 65 biogas plants across Switzerland. They estimate the total biogas plants number, including industrial biogas plants, to be around 80 in Switzerland.

Among the 57'600 farms still remaining in Switzerland in 2011, they estimate the growth potential for biogas plants recycling farm waste to be important. They base their assumption on the facts that only 5% of farm fertilizer from waste are being recycled and exploited.
This low percentage of farm fertilizer recycling could be increasing as in 2010 the excess nitrate balance reached 102'000 tons and the nitrate concentration in underground water is too high in certain regions with an important concentration of farms.
On the demand side for green electricity generated from biogas plant, the fact that Switzerland government decided to phasing out form the nuclear age will generate a large demand for green electricity, among which the electricity produced with biogas form farm waste is a competitive option.

MicroPBR_4D__Dévelop_Application MyBP.pdf

5.7 What is the competitive environment of the project?
strengths, weaknesses, opportunities, threats of the competitive environment.

Strengths:

The strengths of the project within its competitive environment is its innovative content, with the LPU that integrate the microPBR 4D concept with all its innovative content (Dynamic LTI and parametric programs).
The solar digital photosynthesis that allow this LPU, opens a brand new field of possible applications. This LPU could help several industries take a leading position using solar digital photosynthesis .
The LPU is also a new tool filling a current gap for the specific measurements required to quickly and precisely plan microPBR 4D prospects in terms of biomass and energy production for a specifically chosen region.
In deed this LPU offers unique measurements in real time of local variation in UV, PAR, Infra-red but also the specific PAR improvement, the infra-red capture fraction and the photovoltaic potential of excessive light for micro-algae culture. This specific measurement capacity could make it a tool in demand by government or industry willing to develop both biomass production potential and solar energy production in a specific region.

Weakness:

The weakness of the project is the lack of official recognition, the absence of active academical backing and a very competitive environment made of a mixture of public research institutes and big corporations active in the field of micro-algae research. The fact that the microPBR 4D technology, started by this LPU project is at an early and risky stage of industrial development with an absence of financial resources, participates to the weaknesses of the project in its competitive environments.

Opportunities:

The competitive environment offers several opportunities that comes from previous massive investments from governments into fundamental and applied research and from venture capital into micro-algae culture projects that sometime did but often did not reached financial sustainability. Those previous developments combined with new technologies from different field has brought the market of micro-algae culture system to a critical threshold of technological maturity. The development of the microPBR 4D technology could take advantage of the different dense technological clusters present in Switzerland, involved in both micro technology and biotechnology.
Furthermore on the demand side, the combination of global diminution of biomass output from conventional way of production, (due to water pollution, climate stress and other) with an increased demand for biomass and energy coming from demographic growth should allow a micro-algae culture and solar energy mass market to really take off in the decade to come.

Threats:

Among the numerous threats the project is confronted to, a classical threat is a drying of possible resources needed for the growth of the project. The drying could come from competitions cutting off resources with other or similar projects and / or a strategy to repel possible investors with a

negative PR campaign.
Plagiarism of the innovative content is also a threats having a good position in the threats list ranking at this early stage of the project.
A prolonge isolations of the project and a reduction of the different contacts and business relations affiliated to this project is also a potential threats.
Finally an intrinsic threat to the project is a process development to slow to adjust to market evolutions. This speed issue goes from product development, production and to delivery of customized products.

5.8 What are the business risks of the project and how do you plan to manage them?
Strengths, weaknesses, opportunities, threats of the CarboRock start-up project of enterprise:

<u>Strengths:</u>

Game changing technology:
The strengths of the CarboRock start-up project is to bring to market a game changing technology (microPBR 4D) that brings new commercial opportunities as well as filling a technological gap in the waste treatments and modern biomass production in the farming industry.

Innovative delivery:
Another foreseen strength is the delivery of the microPBR 4D trough the sales of cubic meter of active culture and franchises. It can distribute the cost burden of a microPBR facility, bring more fluidity to the microPBR ownerships market and bring a long therm fidelity business relationship through franchises. For the CarboRock start-up project, it reduces capital cost, the required amount of capital for expansion and the long term contracts bring more predictable and sustainable economical growth.

<u>Weakness:</u>

Low acceptance of a new technology:
Offering a new technology or an innovative service is also a weakness as the acceptance for a new methods or to replace a known way of doing things can be low at the beginning. The acceptance of a new technology is proportional to gain in efficiencies or it solve a current problem. MicroPBR should both solve waste disposal problem and make a major gain in biomass productivity.

Technology youth disease:
New technologies are also subject to youth disease and a track record of the way a new technology may age is missing. Computer simulations, on sites measurements with LPU and microPBR pilot plant experiences with careful tracking should give enough maturity to the technology.

<u>Opportunities:</u>

Farming industry mutation and potentials:
The farming industry in Switzerland is under a strong pressure with a constant reduction of the number of farms. However at the same time, the markets that come with diversification of the farming industry into the energy production and high value biomass production for the pharmaceutical and chemical industry, have both high volume and high margin potentials.

From a pioneer position to the lasting advantages of an early implementation:
One of the opportunity of the start-up project would be to take advantage of the network of LPU

measure station to develop a network of microPBR. A network of microPBR integrated in a carbon negative ecosystem would be a really world show case and base to export and adapt the carbon negative ecosystem to other part of the world.

Threats:

MicroPBR 4D popular rejection:
In Switzerland, one of the big issue facing a renewable facility of any kind, weather solar panel, wind turbines or even biogas plant is popular rejection caused by unintended side effects.
The most common side effects are poor integration in the landscape, noises, smells, road traffic increases or just the visual annoyance of an industrial facility and the related damages it could cause to the tourists industry.
This treat of popular rejection is going to be addressed from both the technical-artistic aspect of the microPBR object and the communication side. The microPBR 4D design is intended to cause as little as possible of objective annoyances. To address subjective rejections, a marketing will be done to increase acceptance of the microPBR technology in the landscape.

Technical failures of the microPBR function:
As a results of the relative weakness that a young technology faces, technical failures of any of function of a microPBR in service represent a major treat that could cause serious physical as well as commercial damages.
Since high level of thermal, electrical and chemical energy is processed and under control in a microPBR facility, a technical failure could result into severe damages to third parties, to the reputation and finally to the financial balance sheet of the CarboRock start-up.

Chemical or biological quality issues:
One of the biggest threats of CarboRock startup project is not to be able to maintain the highest level of quality throughout the entire supply chains from nutriments making to ready to sell raw material or value added products. The quality standard will be line-up with organic standards (BIO) for concentrations in heavy metals and chemicals (pesticides, herbicides, dioxins among others) and biological contaminations (virus, bacteria, fungi, other parasites types and GMO contaminations). The technical and management solutions to address those issue exist and it is a matter of proper adaptation of those tools and management techniques to the planned carbon negative industry.

Poor brand management and lost of business culture of integrity:
When it comes to high quality standard involved in the food or pharmaceutical industry, trust in the integrity of service supplier or the quality of the equipment is an important issue.
Trust in the integrity of the service or product provider is also important in the CleanTech industry. For instance, the carbon compensation industry or for the waste treatment facility rely on the trust that the service is effectively performed.
The start-up brand should embody this trust in the integrity of the business culture present in the carbon negative industry.

Supply chains disruptions:
As many other business, the CarboRock start-up will be inside a commercial web and therefore it will be threaten by a supply chain disruptions of any of it suppliers for the raw material for nutriment complement capsules, the sub-contractor for the part of the microPBR and the specific refinery capacities.

Uncontrolled growth:
As long as the CarboRock start-up meets products sales growth prediction, the right amount of resources can be allocated to the development of the start-up. By the very nature of a venture aspect of the CarboRock start-up, a rather intensive, massive and lasting growth is expected. Not

being able to face increasing demand from customer is a commercial treat not to ignore.

Attempt of data's integrity:
The CarboRock start-up will be essentially handling a lot of data and information of many sorts, from technical informations on the microPBR, the information about the micro-algae strains, the strain specific digital photosynthesis parametric program, the industrial waste raw material compositions, the nutriment complement capsules composition, bio-refinery protocoles, the protocole for specific applications of micro-algae biomass, the sun variation specific data and the market data for the raw material and other data. All those informations and data are subject to threats such as lost of data, poor quality of data, corruption of data or data disorder.
Following competitor in a new market:
Being a pioneer of a new technology and opening new big markets brings as many competitors as the size of the market. These potential threats can be a source of stimulations and help develop the overall biotechnology and CleanTech industry. The CarboRock start-up project will follow its strategy to avoid threats from competition with a specialization and adaptation to local environment of its products and services. It will also try to keep its customers with upgrades and quality services and gain new customers with innovative and user friendly new product line.

5.9 Which preliminary investments have preceded this grant application?

A theoretical study based on a meta-analysis of scientific litterature has been performed to develop the theoretical basis behind the microPBR 4D technology that includes the LPU units which is the focus of this CTI project.
Several qualitative designs of LPU have been created in 3D models for early evaluations, as a basis for discussions and for the development of the model of LPU produced at the end of this project.

6. Scientific/Technical Objectives

6.1 What are the basic scientific/technical ideas behind the project?

In a plant field or in a algae pound or other actual devices, the fraction of the solar energy being effectively converted into biomass represent a very small fraction of the overall sun light energy. Furthermore growing a plant field or a algae pound requires energy to run the system, harvest and dry the biomass. These facts make biomass a poorly efficient system to harvest sun energy.
Even though micro-algae culture can offers interesting productivity rate in laboratory with artificial lighting, scaling up those rate into an industrial facility with sun light is a challenge.

One of the fundamental problem being the conversion of sun light energy to micro-algae biomass.

Light interface transfer problem:
For instance 50% of sun light can be reflected on the surface of water. When growing micro-algae like coccolithophore, producing light reflecting particles, light penetration can become a serious issue with a reflectivity of 90%.

Light intensity problem :
An other aspect of that problem is the light intensity the cells are receiving. Micro-algae cell can have an effective photosynthesis in laboratory with an intensity at a the fraction of what's encounter outdoor, even in Switzerland.For instance, the light intensity around the Switzerland can be around 2600 micro-mole / m2 of photon at photosynthetic level. The micro-algae can resist such intensity but can grow in laboratory with as little as 30 micro-mole / m2 and robust growth can be achieved with less than 100 micro-mole / m2. This means that if all the photosynthetic light effectively available penetrated one square meter of culture, the sun light would quickly become saturating.

Light wave length energy level problem :
Another aspect of the sun light energy conversion to biomass problem, is the wave length available in sun light spectrum and the photosynthetic system limits. For instance only a small fraction of the range of the spectrum, from 400nm-700nm, are photosynthetically active. Even within this range, the energy conversion efficiency into biomass is not equal depending on the wave length, 700nm range been more efficient. The UV fraction has energy rich wave length which cannot be used for biomass production and can even cause biological damage. This energy fraction of sun light is lost for the photosynthetic process.

Timing between light dependent reactions and the "dark" reactions:

There is a great diversity of type of photosynthesis among "micro-algae", which include many different types of species in different phylum. Each of which have their own requirements of the light characteristic for an optimal photosynthesis.
For example micro-algae such as coccolithophore are evolved photosynthetic organism with chloroplasts and a photosynthesis close to plant.
In this type of complex photosynthesis with a long chain of reaction between light "dependent" and light "independent" reactions, the difference in the time scale of the successive stages in the chain of reactions are in a logarithmic magnitude.
For example in the first stage of energy transfer in chlorophyll, the time scale is in the femtosecond to picosecond range. As for the time scale of the last stage of carbon fixation, it occurs in the millisecond to second time range.
The overall process rate is limited by the slowest stage. In a continuous flow of photon at the speed of light, their is time for energy to be received but not assimilated in the process. This is leaving the energy arriving at the right place, the right intensity, the

right frequency but at the wrong time, leading to energy being lost for the process.

Micro-algae liquid density limits and correlated energy spending:

Despite the fact that the time for the doubling of the biomass is a lot shorter in micro-algae that in plants, micro-algae culture have a draw back when in comes to the energy you have to invest into the culture. to generate the liquid mass flow required to bring the nutriments and to harvest the biomass.
This energy spending for liquid mass flow and harvesting is directly linked to the biological density in the culture. As more volume of liquid as to be pumped or filtered per unit of biomass as the density decreases.
The density of micro-algae in liquid culture can increase up to a certain concentration beyond which cell flocculates.

What MicroPBR 4D will offer ?

The scientific ideas behind the designed of the microPBR 4D are to address all of the problem mention above in a new generation of photobioreactor that offers three unique characteristics.

- an energy positive facility
- a strain specific digital photosynthesis,
- cell growth beyond liquid culture density threshold limits:

The two main design innovations proposed in the microPBR 4D that bring those characteristic are the light processing unit (LPU) and a light transmitting item (LTI).

The LPU allows the microPBR 4D to be an energy positive device by using solar infrared radiation for energy production, UV conversion to increase PAR (Photosynthetic active radiation) and strain specific digital photosynthesis by diffusing captured and process sun light into discrete flash of light at the right place inside the culture, at the right intensity, the right wave length and the right time.

The LTI allows for biomass to accumulate beyond liquid density limits and at the same time that its support biomass, it bring a path for the light to be effectively transmitted to the biomass.

6.2 What is the scientific/technical state of the art relevant to the project?

Since the microPBR technology hybridized micro-algae culture systems, concentrated solar thermal energy technology and other optic technologies, the state of the art relevant can be summarized in a classification of three main groups of technologies :
Simple classification of micro-algae culture systems (with a specific possible application) :

Microalgae culture systems classification :

1. Pound:
    1. Outdoor pound culture :
        1. Simple pound square or round. (De-pollution/low quality biomass production)
        2. Race pound square or round. (Depollution/low quality biomass production)
    2. Covered pound :
        1. Simple covered pound square or round. (High quality biomass production)
        2. Race covered pound square or round. (High quality biomass production)
2. Sheets or tubes of different geometry : (High quality biomass production)
    1. Outdoor sheets or tubes of different geometry and size.

    2. Outdoor sheets or tubes of different geometry and size with sun reflector.
    3. Greenhouse with sheets or tubes of different geometry and size.
    4. Greenhouse with sheets or tubes of different geometry and size with sun reflectors.
3. Outdoor tank with flexible tube wrapped around it. (Oxygen production / De-pollution / low quality biomass production)
4. Outdoor tank with immobilized algae biomass in gel ball. (Oxygen production / De-pollution / low quality biomass production)
5. Indoor laboratory PBR type, Infors. (Scientific research, production setup)
6. Indoor tank with optical fibers. (Scientific research)
7. Indoor stir tank with Solatube. (High quality biomass production)

Micro-algae culture systems classification table based on qualitative marks in comparison to the state of the art in the field :
Green = better than average in the state of the art
Yellow = within average in the state of the art
Red = below average in the state of the art

	Biohazard regarding biomass quality	Light reflection	Light penetration	Oxygen harvesting	Biological density	Exposition to heat lost	Overall energy balance	Cost per liter of culture
1								
2								
3								
4								
5								
6								
7				?				?
MicroPBR 4D								

Solar thermal energy generation system :

1. Concentrated solar systems
    1. Solar electricity Heat and electricity production with a concrete, myla and air heat transfer based technology for concentrated solar, type : AirLight.
    2. Solar furnace with parabolic mirror and heliostat, type solar furnace Odeillo (Melting metal, hydrogen, heat, electricity, nano material production)

3. Concentrated Solar power plant, type Solar Power Tower, Daggett, Almeria, Sanlucar la Mayor, Albuquerque (Heat, electricity, sea water desalinization)

Modern and mature optic and lighting technology :

The LPU for controlled light diffusion and the LTI for light transfers to a dynamic cell support are innovative technologies with no equivalent ant on the market today. The closest technology will be adapted to become elements of the microPBR units. For instance, tunable lenses of the type found in Optotune product line, according to their expert, could be possible to work on an adaptation and a scaleup to meet the requirements for the projected LPU element.

1. Focus tunable lens at millisecond time range.(LPU).
2. Fluorescent lighting technologies for plant growth adapted chemistry for UV conversion and PAR spectrum improvement.(LPU).
3. Classical technics for optic material design and production found glasses design.(LTI).

6.3 What is the position of the institution in this context?

The research partner can close their knowledge gab on new applications for concentrated solar technology, heat and cold transfer in bioreactor using renewable energies and life cycle controlled equipment.

The research partner can close their knowledge gab on new possible opportunities of applications in a new kind of micro-algae culture.

6.4 What is the added value of the project related to the state of the art?

The project could exploit « Heig-VD » current and past research in the field of heat transfer technologies, heat modelization of building, measurements and bio-reactor prototyping and experience in industrial product development.

6.5 What are the quantified goals?

Current research activities (Diagram microPBR 4D project position):

The microPBR 4D concept has been developed to solve problems encounter when planning the industrialization of coccolithophore culture, namely high reflectivity, a quick sedimentation due to the high density of the limestone shell. It also addresses high cost, energy and land use of current algae system. The microPBR 4D is one of the four elements to develop a carbon negative industry based on the reproduction of an ecosystem with a carbon sink found in nature.

The solutions developed can solve those specific problems to the carbon negative industry but can also be applied to other micro-algae culture to improve productivity and reduce exploitation costs.

The proof of concept of the LPU with a functional prototype is not only a first step toward the development of the microPBR 4D technology but also a tool to enhance current research in carbon negative industry planning.

Due to the specificity of the microPBR 4D, which are the use of sun ray capture with 2 axis heliostat, ray channelling, UV conversion and PAR improvement and digital diffusion, it is difficult to precisely predict biomass production based on current conventional data. In deed, irradiance yearly average data are not taking into account the variation of PAR and UV fraction.

Quantified goals of the LPU:

A full functional LPU unit alone could be used as specific measurement tool of a new kind that could measure outdoor light input data like :

Local variations of:

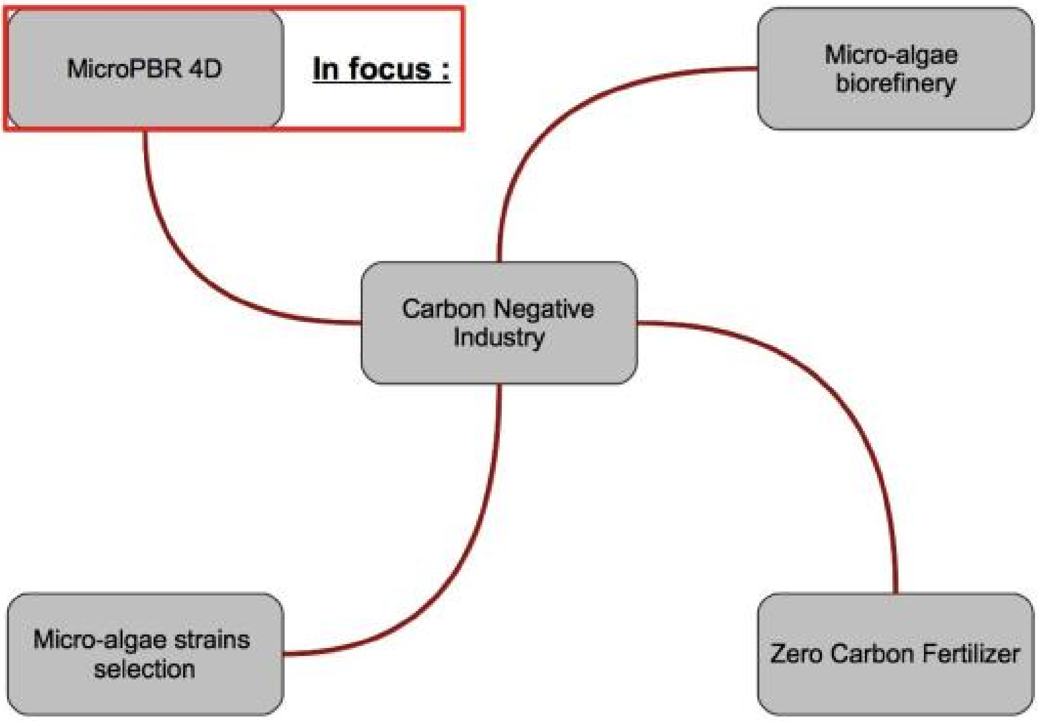
1. Light intensity

2. Light duration
3. UV fraction
4. PAR fraction
5. PAR average photosynthetic yield
6. Infra-red fraction

At the same time, this LPU unit could measure data from the light output of the LPU that goes into a microPBR 4D
like:

1. Light intensity of the light flash output
2. UV to PAR conversion factor
3. PAR fraction improvement factor
4. PAR average photosynthetic yield improvement factor
5. Infra-red energy transferred

Those data taken for a year at specific potential location for microPBR implementation would be useful and highly reliable information.
It would greatly enhance the precision in the planning of the carbon negative ecosystem. There are already several biogas plants in Switzerland and several other under construction or in the planning phase. They represent as many potential microPBR 4D implementation sites. A network of 20 to 30 potential sites could host LPU measurements station for a year. Those data could feed micro-algae growth model and determine the cleaning up balance as well as the biomass and energy production potential for each site. These data from each industrial site could be used to modelized the ecosystem of the carbon negative industry for the Swiss case. My personal interest is that it would speed up the industrialization process.



6.6 What are the scientific/technical challenges in achieving these goals?

The construction of the LPU represent no major theoretical challenge.
There are some challenges with the practical realization of certain part of the LPU, especially when it comes to the scaling up possibilities and heat resistance requirements.

Optical precision design:

One of the practical challenge is a proper optical computer assisted design to allow for theoretical modeling of the unit. It will results in a higher quality of the experimental data.

Heat resistance and scaling up challenges:

Existing technologies have to be modified to use heat resistant material and to have design that allow for scaling up using widely available material.
An hardware have to be constructed to smoothly integrate it all into an efficient unit.
Existing sensor for light parameters have to be selected and integrated at relevant location on the units.

6.7 What are the results of the patent research, if available?

A patent research has not been performed for the technologies developed in the LPU or microPBR.
A part of a default management work package,WP1, is dedicated to this task.

6.8 What kind of new patents are expected?

New patents could be filled for new designs of elements of the LPU like: lenses, hardware, heat transfer solution and the technical solution for their production and their assembly.

7. Project and Financial Plan

Financial Overview

Financial Overview	Total [CHF]	Business [CHF]	Research [CHF]	Cash Contribution to RP by IP [CHF]/[%]		Total Business Contribution [CHF]	Funding Request [CHF]/[%]	
Project Labor Cost	0	0	0	0		0	0	
Additional Expenses	0	0	0	0		0	0	
Total Project Cost	**0**	**0**	**0**	**0**	0%	**0**	**0**	0%

Project Overview

Work Package		W4	W8	W12	W16	W20	W24	W28	W32	W36	W40	W44	W48	W52	W56	W60
Project Management (DEFAULT)	1															
Virtual LPU unit			2													
LPU parts construction and assembly						3										
LPU testing						4										
Milestones						♦ 1	♦ 2				♦ 3					
Labor cost [CHF]						0	0				0					
% of Total project cost						**0%**	**0%**				**0%**					

Work Package	W64	W68	W72	W76	Project Contribution	Labor Time RP/IP
Project Management (DEFAULT)					0%	0%
Virtual LPU unit					0%	0%
LPU parts construction and assembly					0%	0%
LPU testing					100%	0%
Milestones					100%	0%
Labor cost [CHF]						0
% of Total project cost						**100%**

7.1 Project Staff

7.2 Work Packages

PROJECT MANAGEMENT (DEFAULT)

Start date entire project	23.09.2013
Duration entire project	19 months

Project Staff

Activities

Activity
Reporting to partners and stake holder
Controlling the project plan development
Planning meetings and adaptations to project plan
Reviews of patent and related scientific literature
Meetings of the different involved partners
Documentation management of the information produced and related to this project

Goals

Goal
LPU project monitor and review

Deliverables

Deliverable
LPU project plan report
LPU documents archive

Risks / Mitigation

Risk	Mitigation
Lost of Data	Multiple backing program
Poor quality of communication of informations	Active communication follow up
Delay compared to the planning	Evaluation of margin of error and time buffer

VIRTUAL LPU UNIT

Start date (in weeks, relative to entire project begin)	8
Duration (in weeks)	15

Project Staff

Activities

Activity
Acquisition of custumized simulation software suite
Development of Zemax Radiant Light Model of Sun Light source of LPU
Thermic flow simulation in SolidWork
Light reflector design from Radiant Light Model of Sun Light source of LPU
3D CAD simulation of the LPU for thermic and pressure constraint analysis
Development of Zemax Radiant Light Model of digital LPU emissions

Goals

Goal
Use of virtual LPU to develop further microPBR parts
Use of virtual LPU to develop physical LPU for on site measurement platform

Deliverables

Deliverable
Complete and compatible LPU 3D, physical Optic Propagation of light and thermic flow simulations
LPU parts physical requirements
LPU parts and construction plans
Electric diagrams
Animated rendering of LPU construction for user

Risks / Mitigation

Risk	Mitigation
Poor CAD software interoperability	Compatible software
Lost of design updates during work flow	Work flow sequence protocole

LPU PARTS CONSTRUCTION AND ASSEMBLY

Start date (in weeks, relative to entire project begin) 18

Duration (in weeks) 20

Project Staff

Activities

Activity
Meeting with the different construction partners with plans and material caracteristics
Cost and time evaluations for unique prototype and small serie
Coordination of the production of the different parts, adaptation of sensors and data logging tools
Construction of the complete LPU units
Packaging of the LPU

Goals

Goal
Convert virtual LPU into a series of physical LPU

Deliverables

Deliverable
Serie of packed LPU delivered to tester

Risks / Mitigation

Risk	Mitigation
Parts does not meet technical requirement	Clear and comprehensive definition of technical requirements

LPU TESTING

Start date (in weeks, relative to entire project begin) 20

Duration (in weeks) 54

Project Staff

Activities

Activity
Set up of tester network
Organization of transport from assembled LPU to tester
Recording LPU data

Goals

Goal
LPU network implementations
LPU data variation analysis

Deliverables

Deliverable
LPU delived to tester
LPU implementation and set up
LPU data online recording

Risks / Mitigation

Risk	Mitigation
LPU damage during transportations	Careful packaging, robust design of LPU adapted transportation mean
LPU poor calibration	Standards calibrations control
LPU vandalism, stealing during data recording	Careful implementation choice, and safety adaptation on the LPU

7.3 Milestones

VIRTUAL LPU

Due date (in weeks, relative to project start) 23

Required project members

Activities

Activity
Acquisition of custumized simulation software suite
Development of Zemax Radiant Light Model of Sun Light source of LPU
Thermic flow simulation in SolidWork
Light reflector design from Radiant Light Model of Sun Light source of LPU

3D CAD simulation of the LPU for thermic and pressure constraint analysis
Development of Zemax Radiant Light Model of digital LPU emissions

Goals

Goal
Use of virtual LPU to develop further microPBR parts
Use of virtual LPU to develop physical LPU for on site measurement platform

Deliverables

Deliverable
Complete and compatible LPU 3D, physical Optic Propagation of light and thermic flow simulations
LPU parts physical requirements
LPU parts and construction plans
Electric diagrams
Animated rendering of LPU construction for user

Risks / Mitigation

Risk	Mitigation
Poor CAD software interoperability	Compatible software
Lost of design updates during work flow	Work flow sequence protocole

VIRTUAL LPU PRESENTATION

Due date (in weeks, relative to project start) 24

Required project members

Required project members
Hofstetter, Valère

Activities
Goals
Deliverables
Risks / Mitigation

PHYSICAL LPU

38

Due date (in weeks, relative to project start)

Required project members

Activities

Activity
Meeting with the different construction partners with plans and material caracteristics
Cost and time evaluations for unique prototype and small serie
Coordination of the production of the different parts, adaptation of sensors and data logging tools
Construction of the complete LPU units
Packaging of the LPU

Goals

Goal
Convert virtual LPU into a series of physical LPU

Deliverables

Deliverable
Serie of packed LPU delivered to tester

Risks / Mitigation

Risk	Mitigation
Parts does not meet technical requirement	Clear and comprehensive definition of technical requirements

7.4 Additional Expenses

Equipment

Other Expenses

7.5 Cash Contributions (to) Labor Cost

7.6 Comments

8. Intellectual Property

8.1 IPR Declaration

8.2 IPR Contract (Agreement)